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CONTENTS

PAGE

The Prevalence of Coalworkers' Pneumoconiosis. Its Measurement and Significance. A. L. COCHRANE, I. DAVIES, P. J. CHAPMAN, and S. RAE 231

Pneumoconiosis of Kaolin Workers. L. W. HALE, J. GOUGH, E. J. KING, and G. NAGELSCHMIDT 251

Carcinoma of the Lung in Workmen in the Chromates-producing Industry in Great Britain. P. LESLEY BIDSTRUP and R. A. M. CASE 260

Cancer in Coking Plant Workers. D. D. REID and CAROL BUCK 265

The Cytological Diagnosis of Bladder Tumours Amongst Dyestuff Workers. J. G. S. CRABBE, W. S. CRESDEE, T. S. SCOTT, and M. H. C. WILLIAMS 270

The White Cell Count and Exposure to Radiation Hazards. FRANCES M. TURNER .. 277

Dermatitis in Coal-miners. ARTHUR ROOK and GEOFFREY HODGSON 281

Miscellanea:

Occupational Mortality: Coronary Heart Disease. J. N. MORRIS 287

Exposure to Trichloro-ethylene During an Industrial Degreasing Operation. D. E. HICKISH, J. H. SMITH, and JOAN BEDFORD 290

The British Occupational Hygiene Society: First Provincial Meeting 293

The Pneumoconiosis Problem in Coal-mines. C. G. WARNER 293

Chlorine: Its Products and Uses. H. PIRIE 297

Particle Measurement in Industrial Hygiene. G. L. FAIRS 298

Control of the Fluorine Hazard. J. D. PATERSON 301

Book Reviews 304

Index 307

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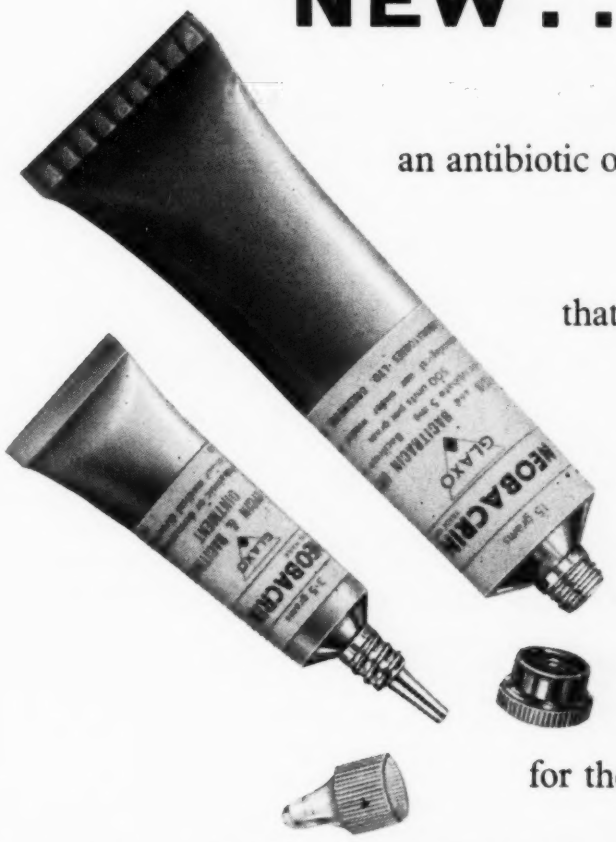

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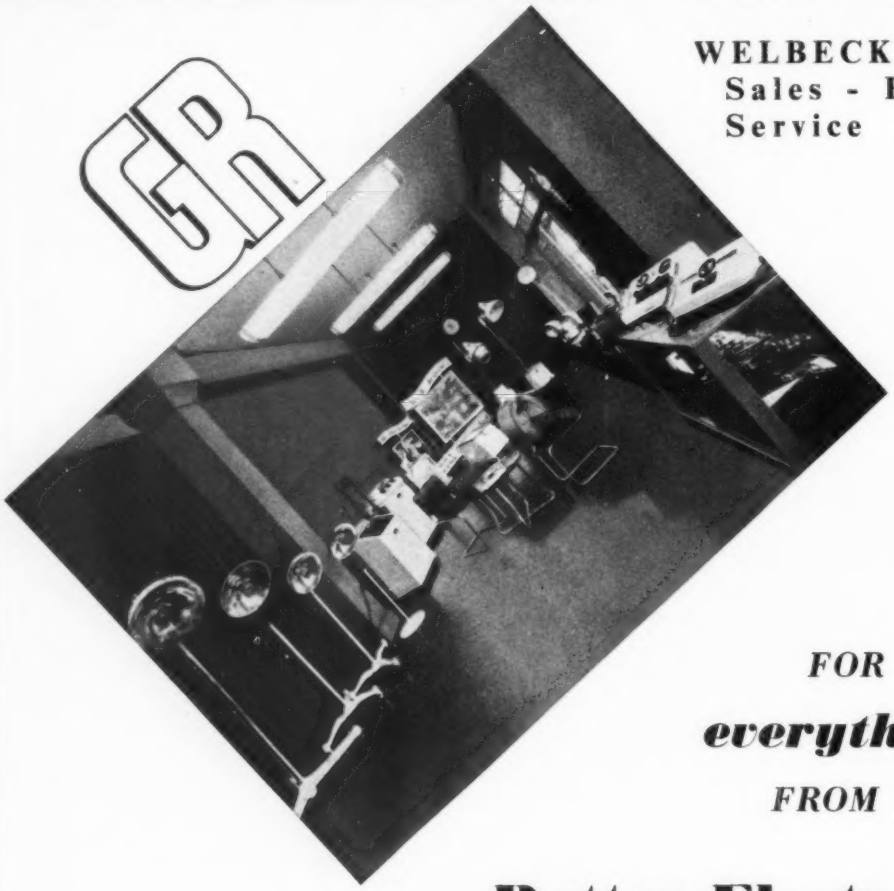

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(Brit. med. J. 1954, 2, 17) (Lancet, 1955, 1, 200) (Brit. med. J. 1956, 1, 727)

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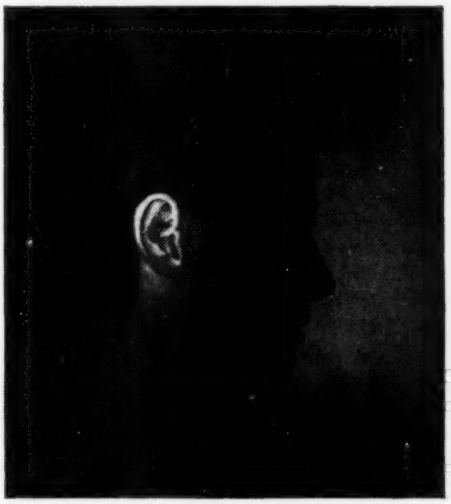

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THE PREVALENCE OF COALWORKERS' PNEUMOCONIOSIS: ITS MEASUREMENT AND SIGNIFICANCE

BY

A. L. COCHRANE, I. DAVIES, P. J. CHAPMAN, and S. RAE

with the assistance of

A. H. RINSLER and M. H. C. WILLIAMS

From the Medical Research Council's Pneumoconiosis Research Unit, Llandough Hospital, near Cardiff

(RECEIVED FOR PUBLICATION JANUARY 18, 1956)

The British medical public have in the past been so well served by the Registrar-General's mortality data that there has been little interest in other medical indices. They may, too, have been unnecessarily discouraged by imagined difficulties associated with the measurement of such other indices as prevalence and attack rate. As, however, interest in the acute killing diseases subsides and increases in the chronic disabling diseases, it is becoming slowly apparent that mortality rates are insufficient. The Registrar-General, for instance, has to disregard rheumatoid arthritis, and information about excess mortality due to coalworkers' pneumoconiosis can be gleaned only by complicated deductions from death rates from other better-known respiratory diseases.

The prevalence rate is not in itself, from a theoretical point of view, a very satisfactory index in that it is a secondary and not a primary epidemiological measurement. It varies directly with the attack rate and indirectly with the case fatality rate. It is thus possible for similar prevalence rates to represent very different attack and case fatality rates. Prevalence is, however, important for two reasons. In the first place, it measures better than any other index the actual load on the community socio-medically as well as from an administrative point of view. It measures the size of a problem. Secondly, a prevalence study is a necessary first step for "forward-looking" studies designed to measure attack rates and progression rates and the factors influencing them. Both these reasons have led the epidemiological section of the Pneumoconiosis Research Unit (P.R.U.) to carry out measurements of the prevalence of pneumoconiosis in many different populations. The results are summarized in this article. The results of investigations into other aspects of pneumoconiosis have been, or are being, summarized in other papers, *e.g.*, the relationship between radiological category and disability (Gilson and Hugh-Jones, 1955; Carpenter, Cochrane, Gilson, and Higgins, 1956); the correlation between simple pneumoconiosis and exposure to dust (Roach, 1953); the relationship between radiological category and expectation of life (Carpenter and Cochrane, 1956); the factors influencing the attack rate of progressive massive fibrosis (P.M.F.) (Cochrane and Miall, 1956); the factors influencing the radiological progression of P.M.F. (Cochrane and Carpenter, 1956); the tuberculous infectivity of P.M.F. (Carpenter *et al.*, 1956); the effect of exposure to coal dust on the attack rate of tuberculosis (Cochrane *et al.*, 1956); and the relationship between simple pneumoconiosis and bronchitis (Higgins, Oldham, Cochrane, and Gilson, in the press).

Methodology

Terminology.—It has not been necessary to invent any new epidemiological indices. "Death rate", "prevalence rate", and "attack rate" are used in the customary and well defined senses. Only two points deserve comment. The word "incidence" has not been used at all, and "attack rate" has been preferred to "inception rate". "Incidence" is, we think, an excellent word, but its original meaning has been so blunted by regular misuse that to use it is to risk being misunderstood. Stocks (1949) suggested that "attack rate" should be reserved for the rate of appearance of infectious illnesses of short duration, but it seems, in general, a pity to have two designations, attack rate and inception rate, for

what is actually the same rate, and of the two "attack rate" is definitely the more usable. The word "lapse" has been used to describe any member of a defined population about whom some required piece of information was not obtained.

Criteria for the Diagnosis of Pneumoconiosis.—The axiom first propounded by the Miners' Phthisis Prevention Committee at Johannesburg in 1916 that "the radiographic appearance in cases of silicosis affords the most reliable single piece of evidence in establishing the existence and actual stage of the disease in any particular case" is certainly true of coalworkers' pneumoconiosis. When our investigations were started, no simple and valid method for the measurement of disturbances of respiratory function which could be used in the field was available, and in any case disability was known to be a relatively late consequence of pneumoconiosis. Moreover, there are numerous other causes of respiratory disability whose prevalence amongst miners might be quite unrelated to that of pneumoconiosis. We therefore decided to make our measurements of the prevalence of pneumoconiosis solely on radiological grounds. For this purpose, we needed a method of categorizing miners' radiographs which was as "simple, repeatable, discriminating, and as valid" as possible (Gilson and Hugh-Jones, 1955).

Details of the P.R.U. classification have been published on several occasions (Davies, Fletcher, Mann, and Stewart, 1949; Fletcher, Mann, Davies, Cochrane, Gilson, and Hugh-Jones, 1949; Cochrane, Chapman, and Oldham, 1951; Cochrane, Davies, and Fletcher, 1951; Fletcher, 1955a), and it has recently been combined with the French classification to form the basis of the provisional European classification. It therefore requires no detailed discussion here. It consists essentially of (1) a division into simple pneumoconiosis and complicated pneumoconiosis, and (2) a further subdivision into three categories, 1, 2, and 3 of simple pneumoconiosis, and four categories, A, B, C, and D, of progressive massive fibrosis (P.M.F.).

We are here chiefly concerned with the value of the classification in relation to the criteria mentioned above.

Although the apparatus is complex and expensive to construct, the taking of a radiograph is essentially a simple matter, but the question of "repeatability" is rather more complex than usual. There are two different types of repeatability involved—technical repeatability and observer repeatability.

The basic question technically is whether a man can be radiographed on two occasions (several years apart) in such a way that the two films when compared together on one screen will be so similar technically that the radiological readings for change will not be biased in any way by slight differences in technique. It cannot be said that this ideal technique has been achieved yet but great strides have been taken towards it, chiefly by means of (1) the "iontomat", (2) the automatic processing unit, and (3) a powerful generator. This subject has been discussed in greater detail elsewhere (Clarke, 1953 and 1955). The subject of observer repeatability has recently been reviewed by Fletcher (1955a) and requires no further discussion here. Fig. 1 illustrates the sort of repeatability achieved by readers in the P.R.U.

1ST. READING

		1	2	3	A	BCD	Total
	269	10					279
1	15	66	9				90
2		8	73	4	1		86
3			1	21	0		22
A			1	2	23	1	27
BCD						48	48
Total	284	84	84	27	24	49	552

FIG. 1.—Comparison between two independent readings of a 1 in 10 sample of all P.R.U. films of miners and ex-miners in the Rhondda Fach. Identical readings = 500 (90·4%).

Discriminating, from the point of view of radiological classification, refers: (*a*) to the ability of the classification to distinguish those exposed to dust from those not so exposed, *e.g.*, its specificity; and (*b*) to the number of groups into which an unselected group of miners, who have been exposed to dust, can be divided at a predetermined level of reproducibility.

The second criterion has already been discussed in connexion with repeatability where we showed that it was possible to subdivide a complete population of miners and ex-miners into six groups at a 90% level of repeatability (Fig. 1). Further subdivision is possible, *e.g.*, into nine groups (0, $\frac{1}{2}$, 1, 2, 3, A, B, C, D), but the repeatability falls below 90%. We consider, however, that the six groups are sufficient for our purpose.

The first point has been fully investigated by Fletcher (1955a). He concluded that the radiological appearance which has been diagnosed as category 1 simple pneumoconiosis is one which is very seldom read by experienced observers in men without dust exposure and that our radiological category 1 does represent an abnormal appearance attributable to dust exposure.

As the classification was based on follow-up studies of coal-miners, the various categories do represent progressive stages in the radiological manifestations of pneumoconiosis, but more detailed enquiry is necessary to discover its relationship to other methods of assessing the severity of the disease.

The relationship to pathological changes has also been dealt with by Fletcher (1955a). In general, it can be said that the rough correlation is good, but difficulties arise when detailed analysis is attempted owing to the selected nature of necropsy material. Work is in progress at present to see what relationship exists between radiological category of simple pneumoconiosis, the category of simple pneumoconiosis as determined from the lung section, and the amount of dust in the lung. Only subjects killed in accidents are being used.

The relationship with disability has been discussed by several authors recently (Gilson and Carpenter, in the press; Hugh-Jones, 1952; Gilson and Hugh-Jones, 1955). The work has proved particularly difficult as the results obtained depend very much on the population sampled and the interpretation of the results is complicated by difficulties inherent in prevalence data.

Some generalizations are, however, possible. All the results agree in suggesting that P.M.F. is a seriously disabling disease, particularly in the higher age groups, while simple pneumoconiosis only causes very slight disability. The most recent work on random samples of populations suggests that categories 1, 2, and 3 in the 55-64 age group correspond, on the average, to increasing amounts of slight disability although some other factor, unrelated to radiological category of simple pneumoconiosis, appears to cause disability in this group (Carpenter *et al.*, 1956). The validity of the radiological classification thus receives general support.

The relationship of the radiological category to expectation of life has been investigated and discussed by Carpenter and Cochrane (1956). In brief, it can be said that there is little evidence that simple pneumoconiosis shortens life but some that P.M.F. does so. The effect of the latter is probably less than previous work had led us to expect. The results do, however, support the " two-disease " hypothesis (Fletcher, 1955b).

Criteria for Diagnosis of Tuberculosis in Presence of Pneumoconiosis.—The great difficulties of accurate and consistent diagnosis of tuberculosis have been clearly demonstrated and fully investigated (Birkelo, Chamberlain, Phelps, Schools, Zacks, and Yerushalmy, 1947; Yerushalmy, Harkness, Cope, and Kennedy, 1950; Garland, 1949 and 1950; Clayson, Frew, McIntosh, McWhirter, McKinlay, and Stein, 1955), and we have confirmed that the British error is of the same order of magnitude as the American (Cochrane and Garland, 1952). The film reading technique which we adopted in our surveys was the same as that recommended by Yerushalmy, so that our errors in the diagnosis of the presence or absence of shadows suggesting tuberculosis or P.M.F. should be as small as reasonable endeavour can ensure. But the diagnosis of tuberculosis in coal-miners is especially difficult because of the presence of opacities due to simple pneumoconiosis and because shadows due to early P.M.F. have also to be diagnosed, and if possible, distinguished from tuberculous shadows. The appearance of early P.M.F. closely resembles tuberculosis of the reinfection type, and one widely accepted hypothesis suggests that P.M.F. is actually a modified form of tuberculosis. Thus, it may be asked whether it is legitimate or logical to attempt to make the distinction. Mann (1951) argued that the distinction could be made and that it was justified by the different progression shown by opacities which he diagnosed as unmodified tuberculosis compared with those which he diagnosed as P.M.F.

We agree that this distinction can be made if there is a high proportion of healed, inactive reinfection type tuberculosis shown on the films diagnosed as tuberculosis. Cochrane and Garland (1952) have shown that the distinction between " clinically significant "* and " inactive, healed " tuberculosis is one which can be made with reasonable consistency and reproducibility in films of non-miners by experienced observers. In our reading of films of miners without simple pneumoconiosis or category 1, we have therefore classified tuberculosis shadows in this way. On the other hand, in films of miners with category 2 or 3 pneumoconiosis, the distinction between clinically significant tuberculosis and P.M.F. is often impossible. We have therefore combined these two groups under the heading of category A (P.M.F.). The justification of such a procedure is that there is a much higher prevalence

*This term indicates that the tuberculous shadow is one which might be active and whose presence indicates that the subject should at least be kept under observation.

(Cochrane, 1954b) and attack rate (Cochrane and Miall, 1956) of such shadows associated with categories 2 and 3 than with categories 0 and 1, and those shadows associated with categories 2 and 3 behave in general as regards their natural history like P.M.F. Those associated with categories 0 or 1 behave in general like tuberculosis (Mann, 1951). Thus, in summary, the convention we have used for the classification of tuberculosis and P.M.F. is the following:—

	P.M.F.	Clinically Significant Tuberculosis	Inactive Tuberculosis
Miners without simple pneumoconiosis or with category 1 simple pneumoconiosis ..	−	+	+
Miners with category 2 and 3 simple pneumoconiosis ..	+		+

We have already shown in Fig. 1 that the consistency of diagnosis of early P.M.F. according to the above convention by the two observers responsible for all our film readings was reasonably satisfactory. It might be suggested that clinical examination or special tests, such as sputum examination, sedimentation rate, or Middlebrook's agglutination test, might assist in the differentiation of tuberculosis and massive fibrosis. The investigators of the American Public Health Service made this distinction in their survey of American anthracite and bituminous miners (Sayers, 1936; Flinn, Seifert, Brinton, Jones, and Franks, 1941) on clinical grounds and this is also the custom of German investigators (Boehme, personal communication, 1950), but we have not found it of value. The only reliable subdivision appears to be into those with tubercle bacilli in their sputum and those without.

The diagnostic convention we have used is convenient for our own comparative purposes, but it is important to realize that our results on the prevalence of tuberculosis and P.M.F. are certainly not comparable with those of other workers. It is also, of course, true that other workers' results are not comparable with each other, nor can they be made comparable until some system of classification of pneumoconiosis and tuberculosis receives international recognition.

The Choice of Population.—The choice and definition of the population in which the epidemiology of pneumoconiosis is to be investigated are of the greatest importance.

Several different types of population have been used by different investigators: (1) Hospital populations of miners; (2) populations of "pensioned" or "certified" miners; (3) selected members of colliery populations; (4) populations of "underground" workers at a particular colliery; (5) populations of "underground and surface" workers at a particular colliery; (6) mining communities where the majority of the adult males are miners; (7) random samples of such communities.

It would seem scarcely necessary to discuss the fallacies involved in the use of the first two populations, but they have been used by reputable authors. Theodos and Gordon (1952), for instance, used what was apparently a hospital population to investigate the prevalence of positive sputum amongst miners. Cazamian (1947) similarly used a population of miners in receipt of pensions for a very detailed epidemiological study, and others have used them for more limited purposes.

The technique of radiographing only certain members of a colliery population was successfully employed by Hart and Aslett (1942) and their team to obtain groups of "home colliers", and it is clearly a valid technique which saves a considerable number of radiographs. However, it involves taking the industrial histories of all miners at the colliery first and then selecting those whom one wishes to radiograph. We were unable to do this as we were "rewarding" those who gave us their industrial histories by taking their chest radiographs and advising them about the findings. We were therefore unable to select only those who had "pure" industrial histories. We have, of course, made use of the "home collier" idea in our subsequent analyses under the term "pure face workers".*

The choice between the remaining four populations depends to some extent on what one wishes to do, where one is working, and how much money and staff are available. A colliery population is always a survivor population and when the disease one is investigating is an important cause of people leaving the colliery, it becomes as important to radiograph those who have left as those who remain. Theoretically, one should aim to radiograph everyone still alive who has ever worked at the colliery under investigation in order to assess the damage done by work in that colliery. This, however, presents major problems in terms of defining and tracing the population, but we probably approached close to this ideal during the Rhondda Fach surveys. A community survey in a mining area is, in fact, the only practical method of estimating the exact prevalence of pneumoconiosis, particularly in areas where its prevalence is high. Such surveys also have advantages in follow-up studies where it is as important to radiograph those who have left the

* A "pure face worker" is a miner who has worked on the coal face at one colliery only and has not been exposed to any other dust risk, apart from his work on the face, likely to cause pneumoconiosis.

colliery as those who remain; in studies of the effect of social conditions on the progression of the disease; in studies of a particular characteristic of a particular type of disease (*e.g.*, the prevalence of positive sputa amongst cases of progressive massive fibrosis); and as providing a defined population which can be sampled when other characteristics of miners and ex-miners requiring more elaborate techniques can be investigated (*e.g.*, physiology). Such work is, however, laborious. In areas where the prevalence of pneumoconiosis is low, and the main object is the search for " 10-year pure face workers " a survey of the underground population is probably sufficient.

Our own technique has been to radiograph the " defined underground population " when we were interested primarily in correlating dust measurements with pneumoconiosis in areas of low prevalence, *e.g.*, England. In Wales (with one exception, where the prevalence of pneumoconiosis was low) we have radiographed the surface and underground populations or done community surveys which will, of course, include both.

Table 1 shows the difference in the prevalence of pneumoconiosis in miners and ex-miners: (1) In a defined underground colliery population; (2) in the " surface " population of the same colliery; (3) amongst the ex-miners in the town in which the colliery stands; (4) in a hospital population of miners and ex-miners serving this town amongst others; (5) amongst 100 consecutive miners accepted as eligible for pensions by the Ministry of Pensions and National Insurance Pneumoconiosis Medical Panel in that area. The differences are so striking that comment is unnecessary.

TABLE 1

% PREVALENCE OF PNEUMOCONIOSIS IN VARIOUS POPULATIONS

	Populations				
Radiological Category	Defined Underground Population at Colliery K	Surface Workers at Colliery K	Ex-miners Living in Town K	Hospital Population at Llandough Miners' Ward	100 Consecutive Cases at Cardiff Panel
0	75·8	74·3	62·3	12·0	0·0
1	12·1	9·2	13·7	7·0	0·0
2	5·7	4·6	9·0	8·0	34·0
3	3·9	5·5	3·7	8·0	25·0
P.M.F.	2·5	6·4	11·3	65·0	41·0

When dealing with colliery populations, the only problem is that of the definition of individuals. Lists supplied by the management of collieries are in general slightly inaccurate. The apparently simple task of supplying an alphabetical list of the men working at the colliery at a particular date, together with their initials, date of birth, address, and registration number, has so far defeated all the collieries that we have visited. This has not been due to any lack of good will on the part of the management and their staff. Two of them went to an enormous amount of trouble in an effort to get a perfect list, but even then they failed. There are many reasons for this: the excessive number of Jones, Williams, Davies, and Edwards in Wales; the rapidity with which miners change their addresses and the slowness with which they inform the management of such changes; the difficulty the management have in discovering why a man is absent—he may be ill or " resting ", or he may be away hop-picking, in Canada, in prison, or even dead. Our experience in tidying up the nominal lists supplied by managements has made very clear to us the difficulties in differentiating between voluntary and involuntary absenteeism. After our first survey we were so discouraged by this problem that we carried out preliminary surveys to define the population at the next two collieries during which only anthropometric data were obtained. As our understanding of the problem increased and our " tidying up " technique improved, we were finally able to do it during the course of the radiological survey.

In community surveys, after the area has been defined geographically, nominal definition can be carried out either by a private census or by progressively correcting electoral rolls and lists of school leavers. The male population can be further subdivided into those who have been exposed to coal dust and those not so exposed by questions at the time of radiographing and by visiting at home those who refuse to be radiographed. The technique in either case is laborious. It is discussed in greater detail in the Rhondda Fach reports (Cochrane, Cox, and Jarman, 1952 and 1955).

The populations referred to in the text consist of 12 colliery populations, designated by the letters A-L. A is an anthracite colliery. The men working there were radiographed by Hart and his radiographs have been re-read to make the readings comparable with ours. B, C, E, and K are collieries in the Rhondda Fach, and D, F, G, and H are collieries in a neighbouring valley. I is an anthracite colliery selected because the dust conditions were thought to be good. J and L are collieries in north-west England selected because the dust conditions were thought to be bad. Many of these colliery populations were radiographed on more than one occasion. The number after the letter signifies the number of the survey at that particular colliery. In addition, use is made in the paper of two other populations, the ex-miners living in the Rhondda

Fach and the random sample of miners and ex-miners living in Town M in the north-west of England.

Percentage of the Population Studied.—The problem presented by those who refuse to cooperate in surveys is both of great interest theoretically and of great practical importance. The time and expense of radiographing the last 10% is equal to that of the first 60%. There would, therefore, be little justification for radiographing more than 50% of the population if we were only interested in prevalence measurements and if the miners came up to be radiographed in a random order. Unfortunately, the measurement of prevalence was often only of secondary interest on these occasions; we were mainly interested in establishing large unselected populations for the purpose of follow-up studies, or in eliminating tuberculosis from an area, and for both these reasons it was necessary to achieve 100%

TABLE 2

PERCENTAGE OF DEFINED UNDERGROUND POPULATION AT 12 BRITISH COLLIERIES RADIOGRAPHED DURING P.R.U. SURVEYS

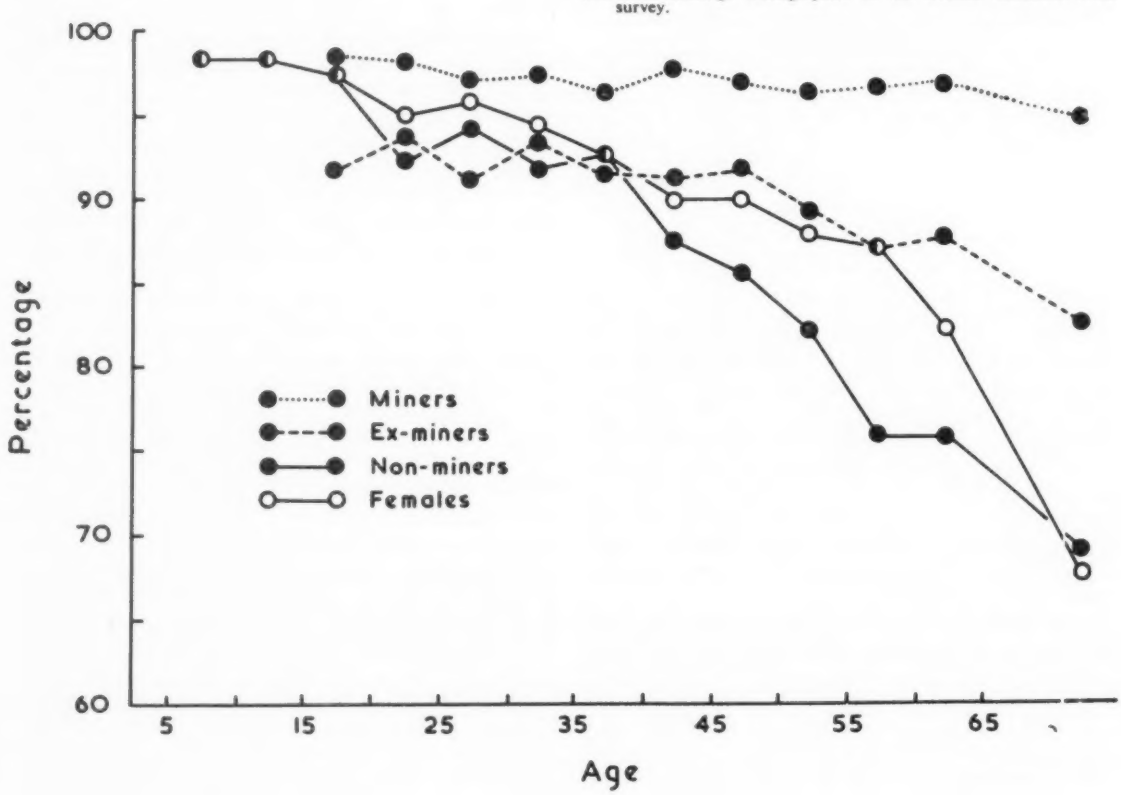
Colliery	No. in Defined Underground Population	No. Radiographed	Percentage Radiographed
A	403	403	100·0
B	707	706	99·9
C_1	536	406	75·7
C_2	560	560	100·0
C_3	554	546	98·6
D	545	544	99·8
E	741	740	99·9
F	532	524	98·5
G	763	754	98·8
H	314	312	99·4
I	502	501	99·8
J	1,247	991	79·5
K	157	157	100·0
L	596	596	100·0

TABLE 3

PERCENTAGE OF MINERS WORKING ON THE SURFACE AT EIGHT BRITISH COLLIERIES RADIOGRAPHED DURING P.R.U. SURVEYS

Colliery	No. of Surface Workers	No. Radiographed	Percentage Radiographed
B	196	195	99·5
C_2	219	215	98·2
D	118	118	100·0
E	244	243	99·6
F	127	124	97·6
G	196	194	99·0
H	90	90	100·0
K	110	109	99·1

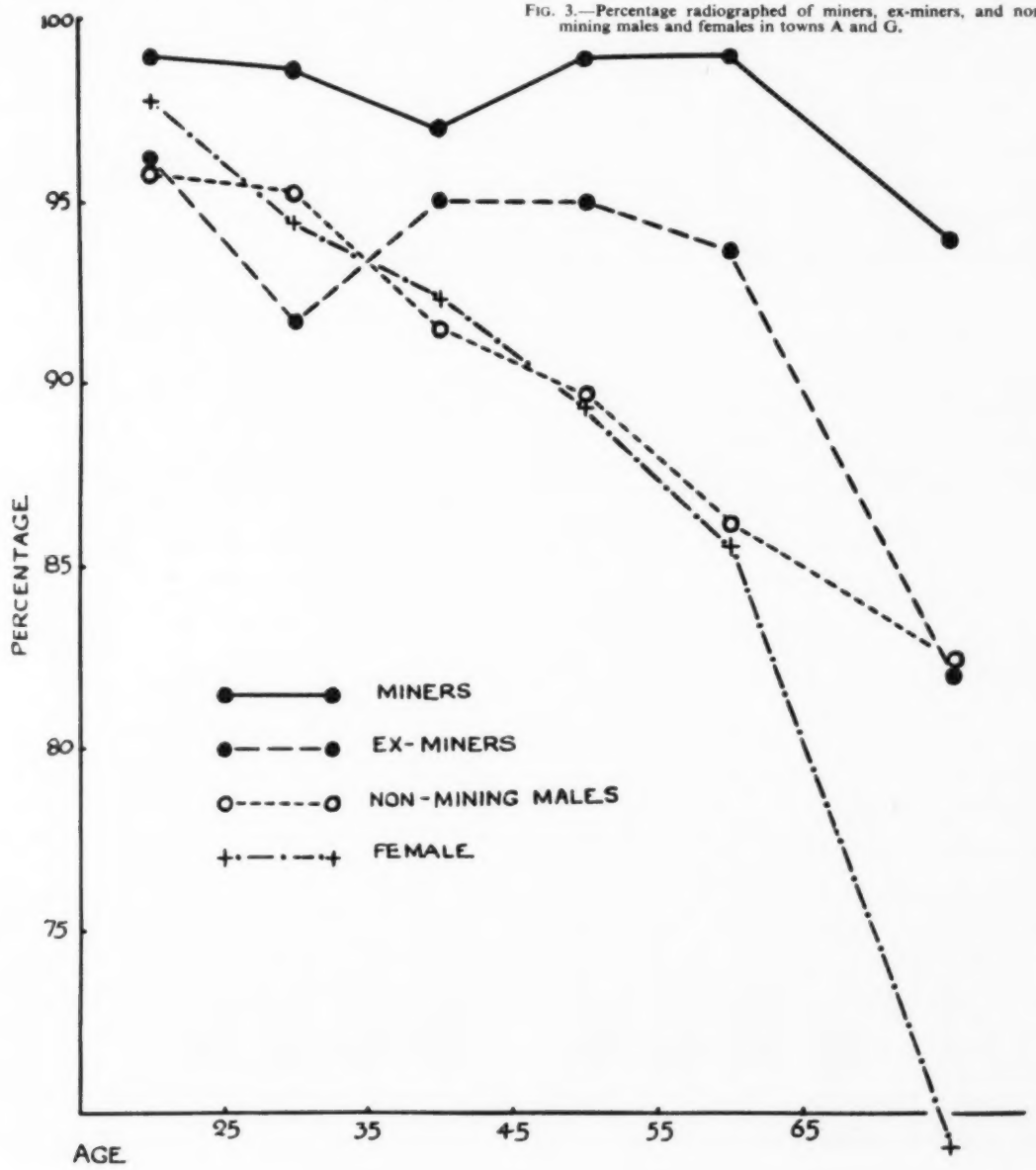
FIG. 2.—Percentage radiographed in the second Rhondda Fach survey.



coverage, if possible. In addition, evidence has been accumulating that people in general, and miners in particular, do not come to be radiographed in random order. The evidence about this has recently been summarized by one of us (Cochrane, 1954a). Pneumoconiotics tend to come up earlier, and those with tuberculosis later, than those with normal films. The first 50% to come up will therefore not give a true measure of prevalence.

There seemed, therefore, every reason to " push " a survey as far as possible, and we have in general been able to keep our lapse rates low. Tables 2 and 3 show the percentage radiographed at 14 surveys of the underground populations and eight of the surface populations. Our results compare favourably with those claimed by other authors. McCallum and Browne (1955) radiographed 89·4% of the surface and underground populations of four Durham collieries; McCallum (1952), when summarizing the results of mass radiography at eight

FIG. 3.—Percentage radiographed of miners, ex-miners, and non-mining males and females in towns A and G.



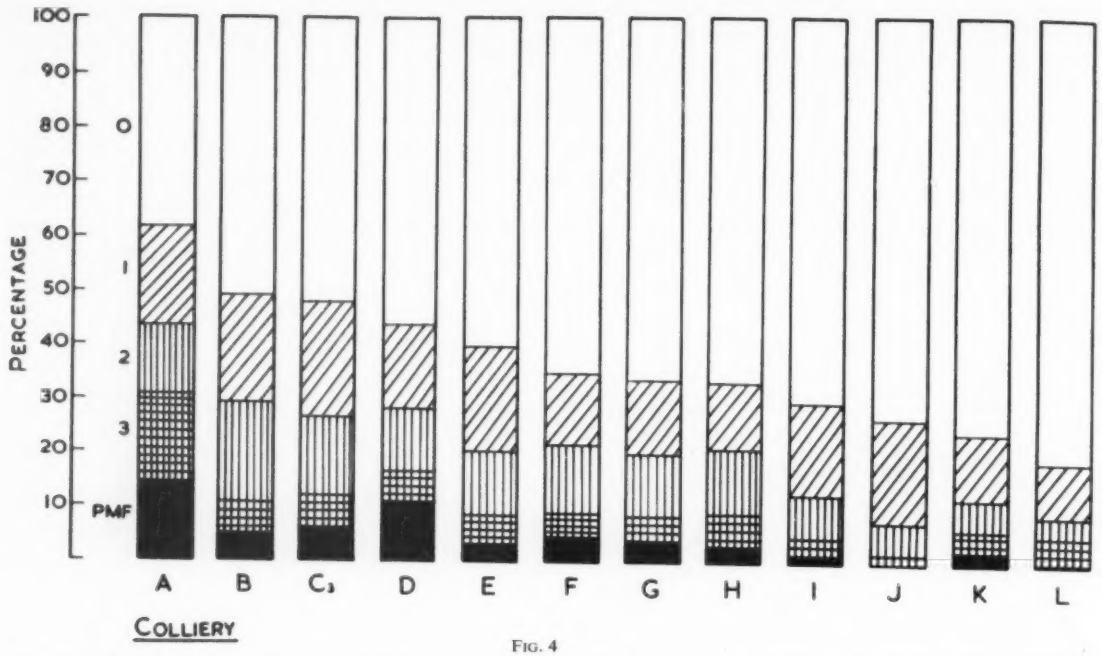


FIG. 4

Northumberland collieries, estimated the percentage radiographed to be 51·7, and Watkins (1950) gives a figure of 67·1% for 10 Midland collieries. The results of attempting to radiograph a complete mining community have been published elsewhere (Cochrane *et al.*, 1952 and 1955). Figs. 2 and 3 are taken from their report.

Results

The figures given in this section are based on

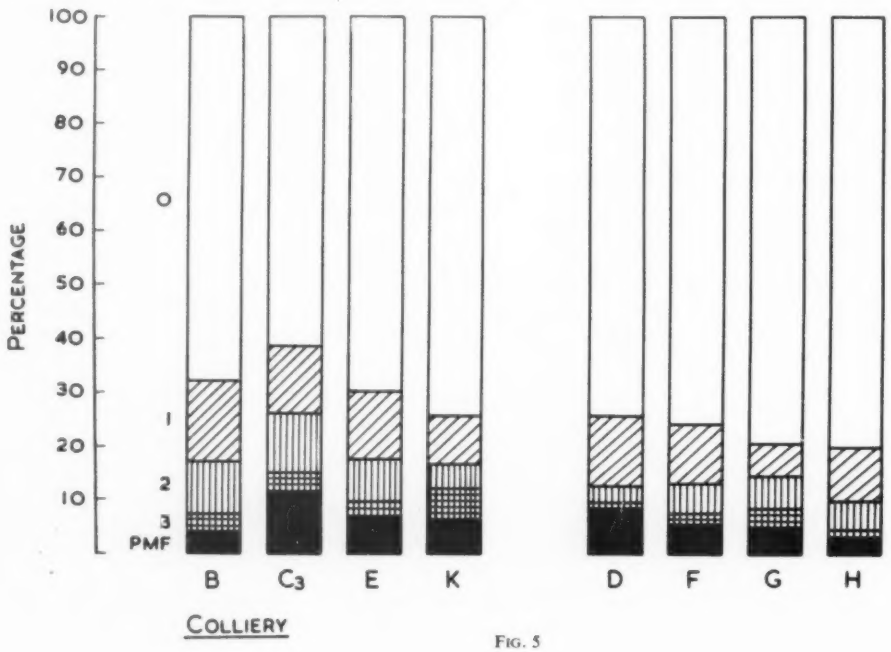


FIG. 5

FIG. 4.—The prevalence of pneumoconiosis amongst miners working underground at 12 British collieries.

FIG. 5.—The prevalence of pneumoconiosis amongst surface workers at eight Welsh collieries.

duplicate readings of large-size films by A.L.C. and I.D., except where other readers are mentioned. Many of the films have been read on several different occasions, sometimes alone, and sometimes with other films for progression readings. In this way, small discrepancies in the figures will be noticed. Although our observer error in film reading is small, it is by no means negligible.

The results of the various prevalence studies can be conveniently grouped as follows:

Prevalence in Defined Underground Population of 12 British Collieries.—Fig. 4 shows the prevalence of disease in 12 British collieries. It demonstrates the general high prevalence of radiological abnormality, and the wide inter-colliery variation.

Prevalence in Defined Surface Population in Eight British Collieries.—Fig. 5 shows the prevalence of pneumoconiosis in the only eight collieries where the surface population was radiographed. It confirms the findings of Hart and Aslett (1942) that there is considerable disease amongst surface workers.

Comparison with Other Published Data.—The dangers of comparing these figures with those of other workers are serious. Different terminologies, different radiological techniques have been used, and different populations have been surveyed. The closest approximations to our figures are possibly those of McCallum (1952) and McCallum and Browne (1955), who not only used our classification but also compared their readings with those of P.R.U. readers. Their figures suggest a somewhat lower prevalence of simple pneumoconiosis and a much lower prevalence of P.M.F. Possible explanations of these differences are discussed in their second paper.

In Ireland, Deeny, Walsh, and Conran (1952), again using our classification, reported the prevalence in two Irish collieries. In one, they found 6·5% simple, and 2·1% complicated, pneumoconiosis, and in the other 1·5% simple and no cases of P.M.F. They used a Schonander miniature *x*-ray set which probably caused them to miss some of the early stages of simple pneumoconiosis, but even so their findings suggest that the prevalence of pneumoconiosis is lower in Ireland than in South Wales.

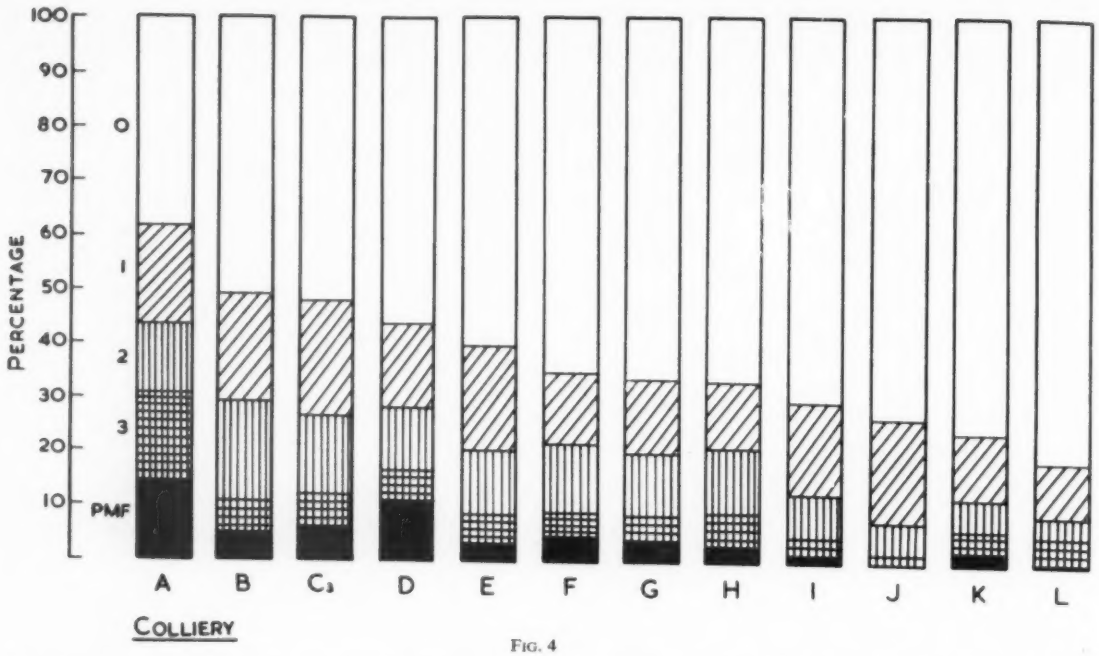
There have been several publications from France, but comparison is even more difficult as, in the past, they tended to concentrate their studies on miners exposed to stone dust, and to use miniature films and a different terminology. The different history of industrial disease legislation in the two countries also introduces difficulties. British miners, when certified as suffering from pneumoconiosis, were for many years forbidden to work in the collieries while there was no comparable law in France. This causes the British prevalence, in particular the prevalence in Welsh collieries, to be artificially low when compared with the prevalence in French mines.

Martin and Roche (1944-45) radiographed 609 miners selected from a large mining area on the grounds that they had been exposed to stone dust. They considered that 16·7% had "images silicotiques" (simple pneumoconiosis) in their radiographs and that 4·9% showed "images pseudo-tumorales" (P.M.F.). The paper is important as being the first in France to draw attention to the fact that exposure to coal dust as well as to stone dust causes radiological changes.

The same authors (Martin and Roche, 1945) published the results of the first systematic radiological survey on large films of miners in France. In 1947 Perret and Mattei (1947) published the results of a radiological survey on small films in the Lamure collieries. The figures, however, refer to a population of 600 underground workers and 1,355 surface workers, which is such an unusual proportion that no comparison is possible with the results of other workers. Their figure for the prevalence of "images pseudo-tumorales" (corresponding roughly to the British B, C, D) is so low (0·6%) as to make it improbable that the prevalence of P.M.F. is high even amongst the underground workers there. Champeix and Thevenoux (1949) surveyed two collieries, and their careful analyses by "years underground" make this a most valuable French contribution. Foubert (1948) added the results of 35 mm. surveys at four collieries in the north of France. Declercq, Balgairies, Flouquet, and Morel (1949) gave the results of seven more collieries from the same region. Neither of the last two papers gave any analyses by "years underground".

Exact comparisons are difficult, but on the basis of the results of the duplicate readings which were carried out between the Douai group and P.R.U. a comparison has been attempted in Fig. 6. Considerable errors are introduced in making these estimates, but two of them will at least counteract one another. The French use of 35 mm. film will tend to make them underestimate the prevalence of simple pneumoconiosis, and the fact that many miners were "certified" before 1948 and had to leave the mines will have a similar effect on the British figures. It seems permissible to conclude that there is a similar prevalence of pneumoconiosis in France as is found in Britain.

In Belgium, the system of radiological classification has been clearly described by Belayew (1950).



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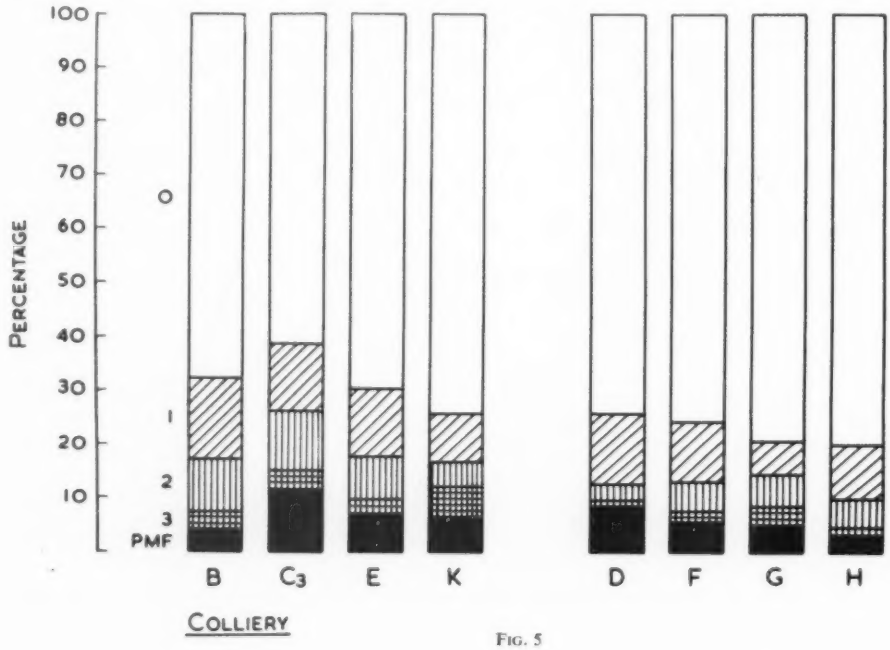

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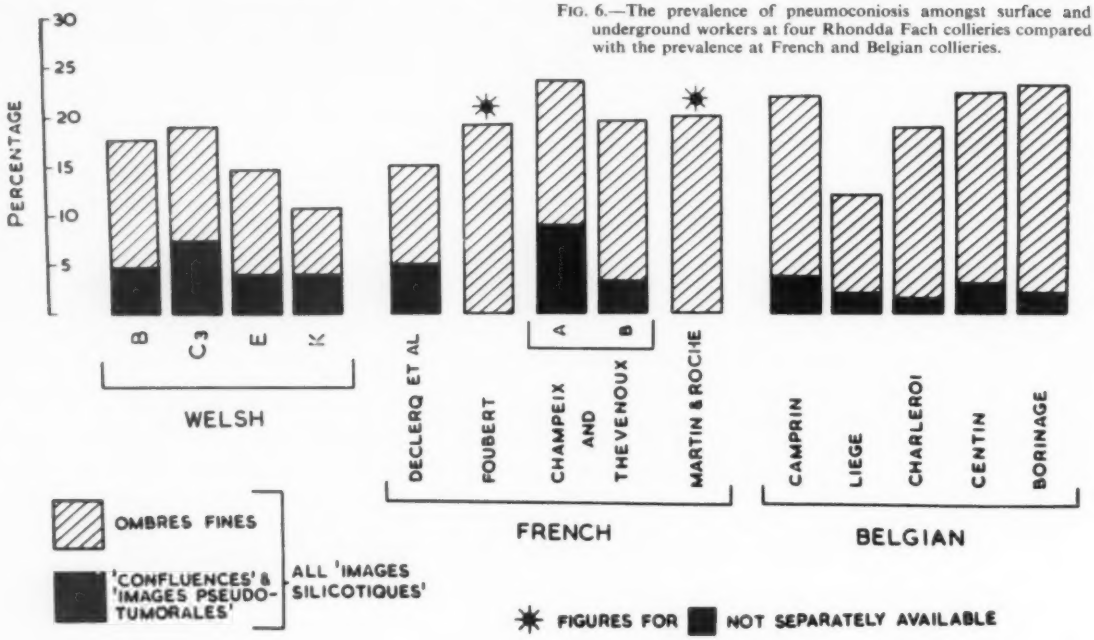


FIG. 6.—The prevalence of pneumoconiosis amongst surface and underground workers at four Rhondda Fach collieries compared with the prevalence at French and Belgian collieries.

We have not, unfortunately, had an opportunity of reading a large number of films in duplicate with them, but we are informed by our French colleagues that the Belgian categories M, P, and N correspond very closely with the similarly designated French categories (Balgairies, personal communication, 1952). It therefore seems reasonable to translate our figures for pneumoconiosis into the Belgian terminology by using the same indices as for the French.

Fig. 6 also shows a comparison between the Belgian figures (van Mechelen, 1951) for the prevalence of pneumoconiosis and our own prepared in the same way as for the French figures. The most striking feature is the relatively high percentage of simple pneumoconiosis combined with a low percentage of P.M.F. This is possibly due to the fact that the Belgian miners go on to the coal face later than Welsh miners.

In Germany there are many papers giving the prevalence of disease amongst those exposed to stone dust (Boehme, 1933; Reichmann, 1949; Zorn, 1949; Worth, Schiller, and Dickmans, 1951), but there are no references to the prevalence in complete colliery populations. This is particularly unfortunate as, owing to the cooperation of our German colleagues in re-reading our radiographs, we are able to translate the German figures with reasonable accuracy.

The only paper referring to the prevalence of pneumoconiosis amongst coal-miners in Holland is that of Appelman (1949), who gives figures for the prevalence of the disease amongst underground mineworkers at Limbourg. It is not clear from his paper whether the 625 miners represent the complete underground population, or if not, how they were selected. He apparently did most of the diagnoses by means of radioscopy and only used films for the severest cases. It is certain, therefore, that his prevalence figure is an underestimate of the real prevalence. His classification is difficult to interpret with any exactitude and particularly his use of the term " reticulation ", but it is clear that the prevalence of P.M.F. at Limbourg is certainly not lower than it is in South Wales.

There have been no new publications dealing with the prevalence of pneumoconiosis amongst coal-miners in the United States or the U.S.S.R., and we have no means of interpreting the data quoted by Hart and Aslett (1942) in terms of our readings.

More Detailed Analysis of Prevalence Data.—The crude prevalence data which have been considered up to the present are clearly unsatisfactory for accurate inter-colliery comparisons. The collieries vary as regards the age distribution of miners working there (Fig. 7), and according to the distribution of the types of employment in the colliery. There may, for instance, be more work on stone with its risk from stone rather than coal dust in some collieries than in others. To make the com-

parisons fairer, various types of analyses can be carried out on the prevalence data. They can, for instance, be broken down by real age, or by industrial age, years underground, years on the coal face, or years on stone. Alternatively, various groups can be excluded from the analyses, *e.g.*, those who have worked for more than a certain length of time at other collieries. None of these tricks is altogether satisfactory, although occasionally illuminating. There are basically only two worthwhile comparisons. The first is the comparison between the "dose response" curves for various collieries (Roach, 1953). This would enable one to compare the risks of getting pneumoconiosis associated with the same dosages of different dusts. The difficulties of obtaining dose response curves for individual pits is, however, very great indeed. The second valid comparison is that of the social and medical damage done by coal dust in different areas. This is best carried out by community surveys so that ex-miners will be included. Such surveys, if the lapse rate is low and they can be analysed by age, give a very fair picture of the damage. Unfortunately, this is only available for one area (Cochrane, *et al.*, 1952). We must therefore content ourselves for the moment with less satisfactory comparisons.

Another point should be noted. Simple pneumoconiosis has had in the past in Wales a relatively high radiological attack rate. Its radiological recovery rate is nil as far as we know and the case fatality rate is very low in comparison with the attack rate. The prevalence rate thus becomes nearly proportional to the attack rate. At the same time, as the technique of analysis becomes more and more refined, *e.g.*, by "years underground and years on the coal face", the "X" axis becomes more and more closely related to dust dosage, and we slowly approach the dose response curve (Roach, 1953).

It would, however, be tedious to give analyses of all the colliery and community populations by all the possible techniques as the evidence is essentially similar for all, so a few illustrative examples are given of each technique.

FIG. 7.—Age distribution of all underground workers at 12 British collieries.

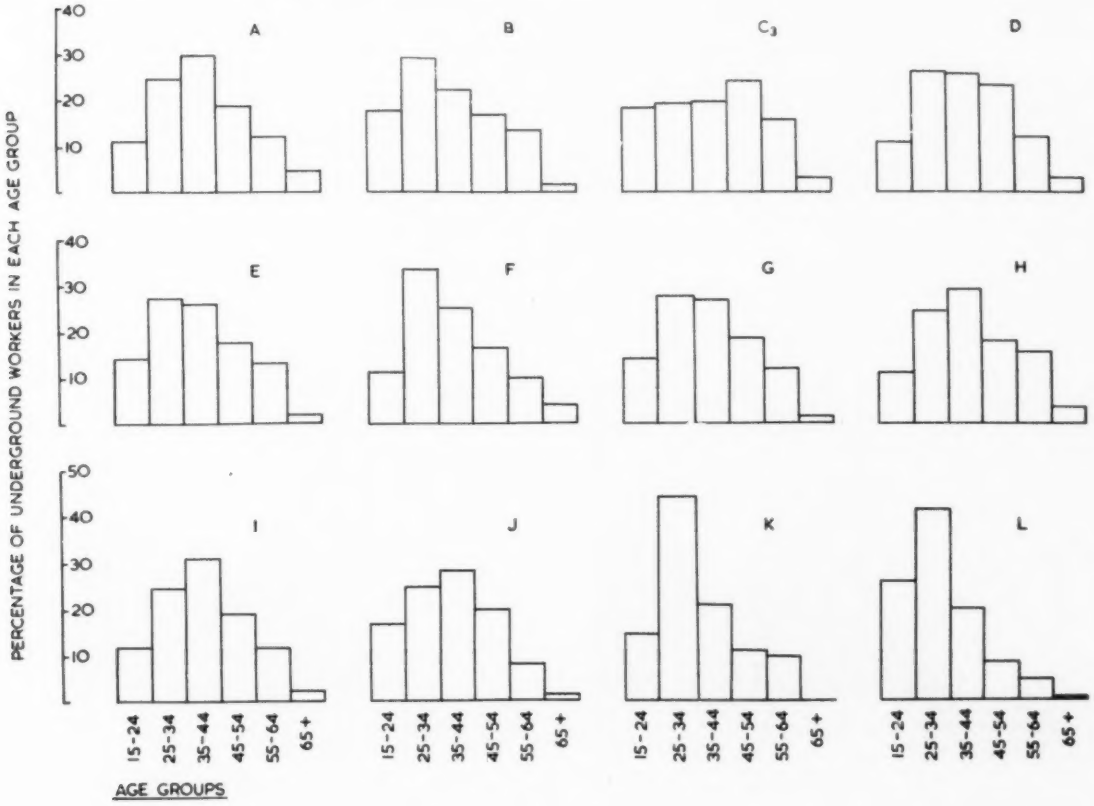


FIG. 8

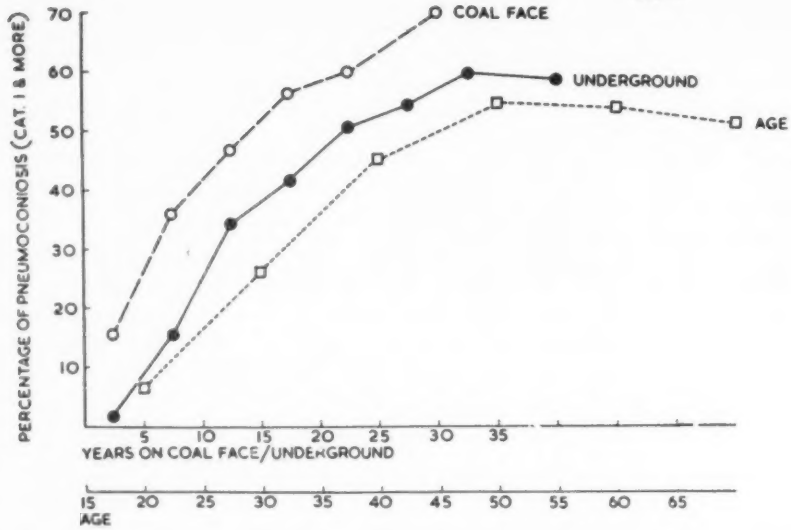


FIG. 8.—Prevalence of pneumoconiosis (category 1 and more) in the underground populations of 12 British collieries.

FIG. 9.—The prevalence of coal-workers' pneumoconiosis amongst those radiographed of the miners and ex-miners in the Rhondda Fach in 1950/51 and 1953.

Analyses by Age.—Fig. 8 shows an analysis of all the 12 underground populations by age and radiological category. It will be seen that after the age of 50 there is very little correlation between age and radiological status. This is probably due to several factors: (*a*) the fact that men with the more advanced radiological categories tend to leave the underground population, so that we are, in fact,

FIG. 9

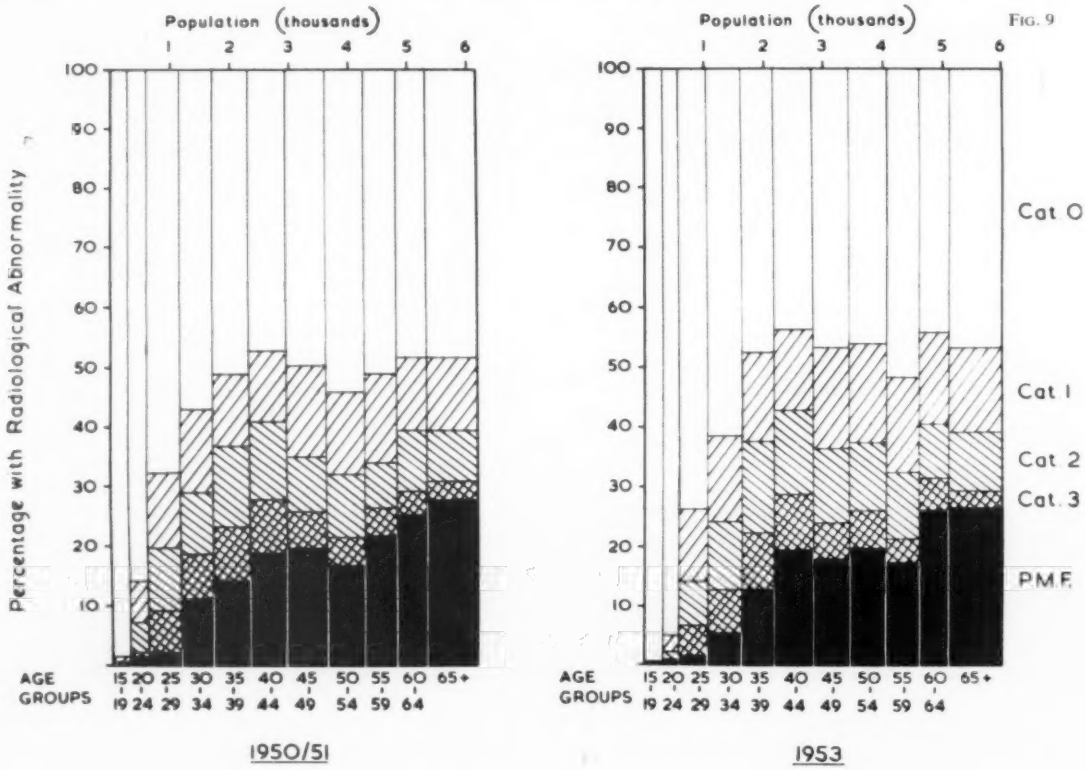
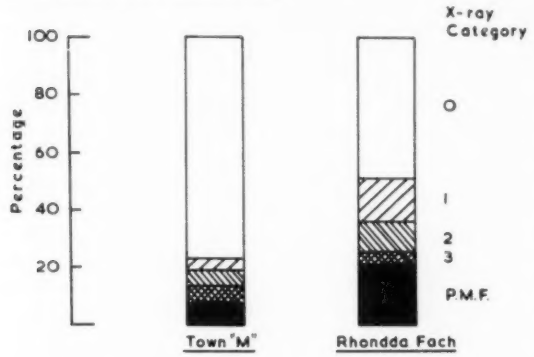


FIG. 10.—The prevalence of coalworkers' pneumoconiosis amongst those radiographed in a random sample of the miners and ex-miners age 55-64 in town M compared with those in the same age-group in the Rhondda Fach.



dealing with a survivor population in those age groups; (*b*) the tendency of miners to leave the coal face at that age and take up some occupation with a lower dust risk; (*c*) the fact that dust concentrations were almost certainly much lower 40 years ago. Fig. 8 also confirms our assumption that our radiological category mirrors the natural history of the disease.

In Fig. 9 the total population of miners and ex-miners living in the Rhondda Fach has been analysed by age and radiological status. As already mentioned, we believe that a total population of this kind is the best index for comparisons when the social and administrative aspects of pneumoconiosis are the main interest.

We also have figures for the prevalence of pneumoconiosis in the town of M, but only in the age group 55-64. The figures are based on a random sample of men of this age living in the town. The total size of the sample was 245, of which 145 were miners or ex-miners (using the same definitions as were used in the Rhondda). Of these 145, 134 (92·4%) were radiographed and the prevalence of pneumoconiosis is shown in Fig. 10, where it is compared with the same age group in the Rhondda Fach. The town M was in a mining area where the prevalence of pneumoconiosis was believed to be low, but there is probably a considerable amount of P.M.F. all over the country in the mining areas.

Analysis by Years Underground.—This is clearly rather more closely related to dust dosage than age, and as a result, a slightly better relationship with radiological category is found (Fig. 8).

Analysis by Years on the Coal Face.—This index is even more closely related to dosage than the previous one. Fig. 8 shows a much smoother relationship with radiological category, and suggests that the attack rate of pneumoconiosis on the coal face has been very high in the past.

Changes in Prevalence.—Several colliery populations have been radiographed on more than one

FIG. 11.—The prevalence of pneumoconiosis categories 1 and more in the radiographed underground population of colliery L in 1949 and 1952.

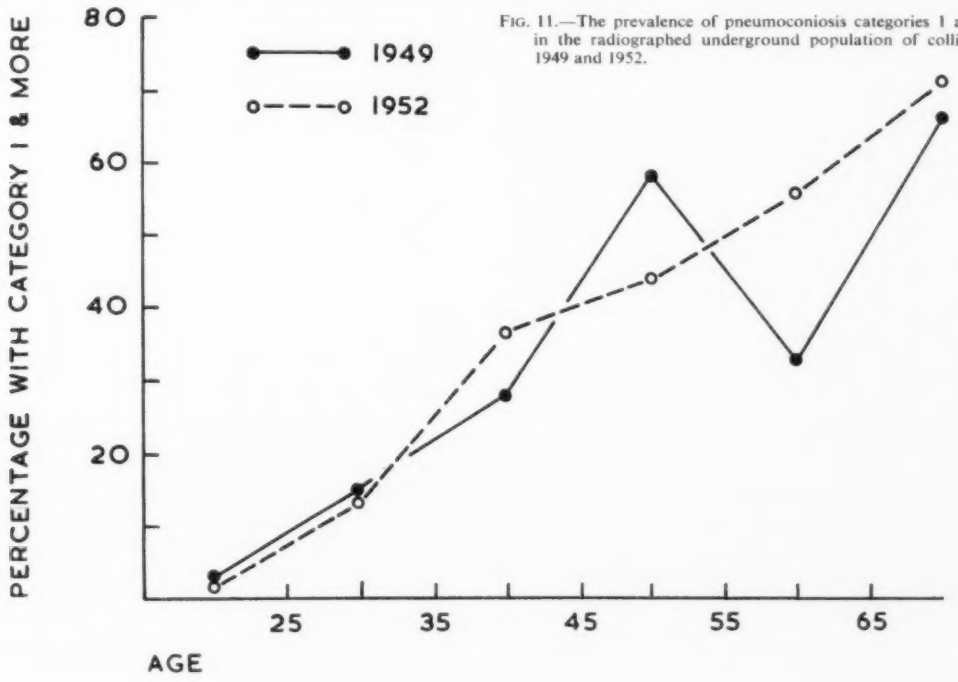
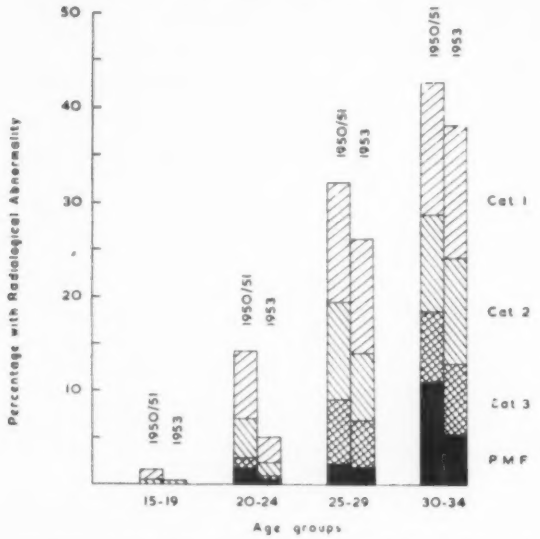


FIG. 12.—The prevalence of coalworkers' pneumoconiosis amongst the younger age-groups of the miners and ex-miners radiographed in the Rhondda Fach in 1950/51 and 1953.



occasion and the prevalence figures can be compared. The great problem is their interpretation. A marked increase in prevalence may be due to: (1) more miners without than with pneumoconiosis leaving the colliery; (2) a high attack rate of simple pneumoconiosis inside the colliery; (3) miners, entering the colliery between the surveys, having a higher prevalence of simple pneumoconiosis than those who left; (4) a systematic change in the level of reading radiographs.

In Fig. 11 the prevalence of pneumoconiosis in Colliery L in 1949 and 1952 is compared. Superficially there appears to be very little difference, but when the material was analysed in detail it was clear that definite progression occurring amongst the pneumoconiotics was being balanced by the number of miners with pneumoconiosis who had left the colliery.

Changes in the prevalence of pneumoconiosis amongst whole communities are somewhat more reliable. The prevalence amongst miners and ex-miners in the Rhondda Fach at the time of the surveys in 1950/51 and 1953 is shown in Figs. 9 and 12. (It should be noted that these diagrams are based on our 1953 readings of the films. At the time of the second survey, we were particularly interested in the attack rate of P.M.F. and thus read A shadows at a level definitely below our standard A shadow film.) Even in this case, it is difficult to interpret all the details. The difference in prevalence in the younger age groups, if correct, appears important but it must be remembered that, first, the difference might be an artefact due to film technique or readers' bias. We do not think that this is the explanation but it is difficult to exclude. Secondly, if it is a true finding there are several possible explanations. Some of this group were radiographed on one occasion and not on another, some left the area, and a few died. Such factors could in certain circumstances produce a difference in prevalence which had nothing to do with a change in the attack rate of the disease. We do not, however, think that this is the explanation in this case. We believe that the simplest explanation of the findings is that there has been a true fall in the attack rate of simple pneumoconiosis and P.M.F. in relation to age. This fall, as far as simple pneumoconiosis is concerned, is probably partly due to the later age at which mining entrants reach the coal face today and partly to a reduction in the dust concentrations in the collieries. The fall in prevalence of P.M.F. is probably partly due to the lower prevalence of simple pneumoconiosis and partly to the reduced tuberculous infectivity in the area (Cochrane and Miall, 1956).

Relationship between Prevalence and Other Characteristics of the Population.—Many of the more important relationships have been adequately summarized elsewhere, *e.g.*, with pulmonary disability (Gilson and Hugh-Jones, 1955; Gilson and Carpenter, in the press), with expectation of life (Carpenter and Cochrane, 1956), with pulmonary tuberculosis (Cochrane, 1954b; Cochrane *et al.*, 1955), with anthropometry (Oldham, 1953; Cochrane and Miall, in the press). We are here concerned with some other relationships which have not previously been discussed.

Relationship with E.S.R. Measurements.—The ease with which the E.S.R. can be carried out in practice and the simple numerical form in which it can be expressed made it inevitable that it would be carried out on large numbers of miners. Moreover, Stewart (1948) regards the E.S.R. as a good index of progression. In a sense, this has been unfortunate as too little is known about the distribution of E.S.R. values in normal populations for this to be of much value. What are needed are the E.S.R.s of those members of a large defined population who have passed some clinical test for normality. The results published by Bruusgaard (1950) and Dahlberg (1948) approach this more closely than others, but still fall short.

During the last 15 years there have been several references in the literature to the relationship between the erythrocyte sedimentation rate and industrial pulmonary disease. Sen (1937) recorded that the sedimentation rate was accelerated in a

number of cases of coalworkers' pneumoconiosis which he examined in South Wales but he gave no actual figures. Craw (1937) performed sedimentation tests on a group of haematite miners and found that acceleration of the E.S.R. only occurred when gross shadowing was seen on the radiograph. He obtained normal readings from 14 men with silico-siderosis of simple nodular type. Heimann (1946) pointed out that an abnormal E.S.R. could be found in cases of simple silicosis as well as in cases with coalescent shadowing, although he did not attempt to draw any conclusions from this observation. Caplan (1947), on the other hand, stated that in miners with " uncomplicated pneumoconiosis " from the Kolar Goldfields, the E.S.R. was normal and only occasionally raised in tuberculo-pneumoconiosis. Tortori-Donati (1947), who examined 103 Belgian coal-miners, found slight acceleration of the E.S.R. in association with radiological reticulation, nodulation, and nodulation with coalescence. He suggested that the sedimentation rate increased when progressive lesions were present, and that this increase was evidence in favour of the theory that coalescent shadows were caused by infection. He attributed the abnormal E.S.R.s in the early stages of the disease to bronchial catarrh.

In Germany, Schmidt (1949) found some correlation between radiological category and sedimentation rate. His population consisted of 2,000 miners applying for pensions and no steps were taken to exclude those suffering from other diseases. He was also using the original I, II, and III classification of *silikose* which would include some early P.M.F. In France, Nadiras, Batique, and Michot (1948) also came to the same conclusion. They studied 850 miners, the majority of whom were seen in the course of routine examinations. They found an increasing percentage of abnormal sedimentation rates corresponding to increasing abnormality in the radiograph. The differences between *reticulation*, *micro-nodulaire*, and *nodulaire*, which correspond to simple pneumoconiosis, are small, and it seems possible that the differences could be accounted for by the different age distribution, for which Nadiras *et al.* make no allowance. Their results for *formes confluentes* and *formes pseudo-tumorales*, which correspond to P.M.F., are similar to ours. On the other hand, Saita (1945) found the E.S.R.s of early and nodular silicosis to be normal.

Our own material consists of the results of sedimentation rates carried out on miners and ex-miners in five different populations. For those studied in Population B by one of us (M.H.C.W.) the Wintrobe technique was used. For all the others the technique was that of Westergren. Population A consists of miners and ex-miners who were in the Unit's ward at Llandough. Population B consists of volunteers from amongst miners working at Colliery C. No particular care was taken to exclude those suffering from diseases other than pneumoconiosis likely to affect the sedimentation rate. Population C consists of working miners selected at random from the defined underground population of Colliery C (two and a half years after the previous investigation) to fill an age-radiological category " square ". Great care was taken to exclude all diseases other than pneumoconiosis which might affect the sedimentation rate. Population D consists of a group of volunteers from amongst the miners and ex-miners living in the Rhondda Fach, with A and early B shadows who were examined before a therapeutic trial. Some, but not all, of those suffering from other diseases, have been excluded. Population E is that used by Gilson and Hugh-Jones for their large-scale physiological experiment (Gilson and Hugh-Jones, 1955). For details of the method of selection, the reader is referred to their report. Briefly, it represented an attempt to obtain a sample of all miners and ex-miners weighted by age and radiological status. The majority of other diseases were excluded but the criteria were not so strict as in Population C.

TABLE 4
NUMBER OF MINERS AND EX-MINERS IN VARIOUS AGE-RADIOLOGICAL GROUPS IN FIVE POPULATIONS

		Radiological Categories				
Population	Age Group	0	1–2	3	A	B.C.D.
A	± 35	2	4	9	4	9
	± 45	1	4	4	4	23
	± 55	1	9	4	4	13
B	± 35	6	13	7	–	—
	± 45	3	8	3	2	–
	± 55	3	11	3	2	–
C	± 35	8	8	8	3	–
	± 45	8	8	7	7	–
	± 55	8	8	8	5	–
		A			B	
D	± 35	30			11	
	± 45	42			31	
	± 55	8			5	
		Normals—Never a Miner	0	1-2	3	C	D
E	± 35	10	8	8	8	8	6
	± 45	10	7	8	8	8	7
	± 55	10	6	8	8	7	8

The results are given in Tables 4, 5, and 6. They all suggest that a man with P.M.F. will probably have a higher E.S.R. than one of the same age with a radiograph normal as regards dust or one with simple pneumoconiosis. They also illustrate what varied results can be obtained according to the population examined and the type of selection.

TABLE 5

AVERAGE AGE AND SCATTER IN VARIOUS AGE-RADIOLOGICAL GROUPS IN THE FIVE POPULATIONS

Population	Age Group	0	1-2	3	A	B.C.D.
A	± 35	36·0 (35–37)	35·5 (34–37)	35·2 (33–39)	34·2 (31–39)	36·9 (35–39)
	± 45	47·0	47·25 (46–49)	42·5 (40–47)	43·25 (40–47)	44·7 (41–49)
	± 55	55·0	52·7 (51–63)	56·5 (54–60)	59·0 (51–62)	55·4 (50–59)
B	± 35	35·7 (29–39)	33·9 (30–38)	32·6 (30–34)		
	± 45	42·3 (40–47)	44·9 (41–48)	44·3 (40–49)	42·0	
	± 55	52·0 (50–53)	53·0 (50–57)	51·3 (50–53)	53·5 (50–57)	
C	± 35	34·5 (31–37)	34·6 (33–38)	34·25 (31–37)	35·0 (31–38)	—
	± 45	45·25 (43–47)	45·0 (43–47)	45·9 (43–47)	45·4 (42–49)	—
	± 55	52·6 (51–57)	54·5 (53–58)	55·5 (54–59)	56·0 (53–60)	—

Population	Age Group	A	B
D	± 35	35·9 (30–39)	34·9 (30–39)
	± 45	44·9 (40–49)	44·4 (40–49)
	± 55	50·25 (50–51)	50·04 (50–51)

Population	Age Group	Normals—Never a Miner	0	1–2	3	C	D
E	± 35	35 (33–37)	35·5 (34–38)	35·4 (34–37)	35·6 (32–39)	36·1 (34–38)	35·8 (31–39)
	± 45	43·7 (41–47)	45·1 (41–49)	44·6 (41–46)	45·0 (42–48)	44·0 (41–47)	45·4 (43–47)
	± 55	54·3 (52–58)	54·0 (50–56)	54·2 (53–55)	54·9 (53–59)	55·1 (51–57)	55·0 (51–60)

TABLE 6

AVERAGE E.S.R. AND SCATTER IN VARIOUS AGE-RADIOLOGICAL GROUPS IN THE FIVE POPULATIONS

		Radiological Categories				
Population	Age Group	0	1-2	3	A	B.C.D.
A	± 35	4·5 (1–8)	5·5 (3–10)	4·9 (1–14)	27·0 (3–90)	28·1 (8–63)
	± 45	5·0 —	13·5 (10–22)	13·0 (2–35)	11·25 (4–19)	31·5 (4–90)
	± 55	5·0 —	18·3 (5–37)	12·25 (4–23)	11·25 (4–29)	27·8 (3–92)
B	± 35	4·2 (2–6)	7·3 (1–18)	7·4 (2–13)	—	
	± 45	5·0 (1–12)	14·1 (2–48)	8·3 (8–9)	16·5 (15–18)	
	± 55	5·3 (3–9)	11·7 (4–25)	7·3 (3–10)	18·0 (8–28)	
C	± 35	6·75 (2–11)	4·1 (2–6)	4·4 (2–8)	7·75 (5–13)	
	± 45	6·0 (2–11)	5·25 (3–8)	4·4 (2–7)	8·9 (6–13)	
	± 55	4·9 (3–7)	5·9 (3–15)	7·0 (2–18)	12·6 (2–25)	

Population	Age Group	A	B
D	± 35	9·7 (1–41)	9·1 (3–25)
	± 45	8·6 (1–33)	11·3 (3–42)
	± 55	17·1 (2–94)	8·2 (4–13)

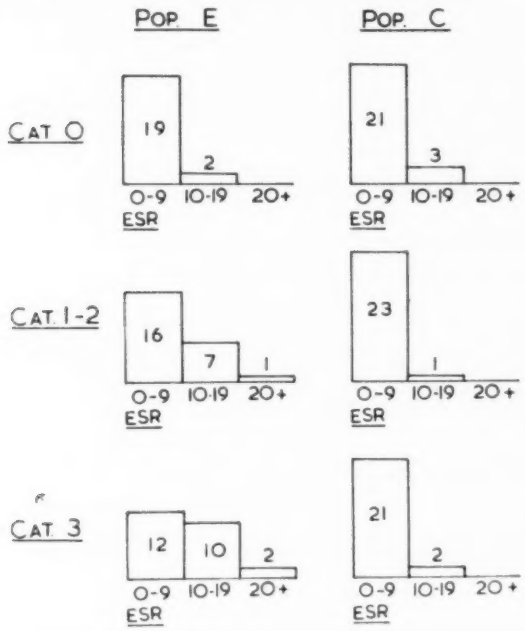
Population	Age Group	Normals—Never a Miner	0	1-2	3	C	D
E	± 35	4·1 (2–5)	5·7 (1–12)	6·7 (1–12)	5·4 (2–10)	23·4 (2–63)	26·7 (14–62)
	± 45	4·9 (2–7)	3·4 (1–7)	9·7 (5–22)	8·1 (2–21)	27·9 (6–70)	24·3 (10–45)
	± 55	9·4 (3–18)	5·7 (2–15)	6·7 (3–11)	13·9 (4–23)	15·4 (3–33)	37·0 (14–100)

The only approach to such an untidy mass of material is to ask certain specific questions and see if clear-cut answers can be deduced.

(1) Is there any relationship between the finding of tubercle bacilli in the sputum of pneumoconiotics and a high E.S.R. ? There has been considerable discussion in the literature as to the relationship between silico-tuberculosis and the sedimentation rate (Schmidt, 1949; Nadiras *et al.*, 1948; Saita, 1945). The problem seems of rather limited importance. The diagnosis of silico-tuberculosis on radiographs alone is subject to such large inter- and intra-observer error as to be of little value. The only useful definition of silico-tuberculosis is that of a " case of P.M.F. with a positive sputum " and it is therefore only necessary to do a sputum examination in addition to the radiograph. Nadiras *et al.* (1948) have pointed out that such cases do, in fact, on the average, have a higher sedimentation rate than other cases of P.M.F., but the sedimentation rate cannot replace the sputum examination. It might be used to select cases of P.M.F. for sputum examination but it is our experience that this is better done on the basis of cavitation in the radiograph, and recent history of loss of weight.

(2) What, if any, is the relationship between E.S.R. and radiological category ? There is general agreement that cases of P.M.F. have, on the average, higher E.S.R.s than cases of simple pneumoconiosis.

FIG. 13.—Comparison between E.S.R. and radiological status in two populations.



Interest is chiefly centred on the relationship between E.S.R.s and the categories of simple pneumoconiosis, and from two points of view: (*a*) If there were a regular and significant increase in average E.S.R. with radiological category there would be some additional support for the validity of our radiological classification. (*b*) If, on the other hand, all cases of simple pneumoconiosis had normal E.S.R.s, there would be additional support for the theory that it is simply dust retention with minimal fibrosis without any infectious element, as others have suggested, and would indirectly give support for the "two-disease" hypothesis.

To investigate such a point accurately one would require a random sample stratified for age and radiological status from a large well-defined population of miners and ex-miners from whom all those with abnormalities likely to raise the E.S.R. other than pneumoconiosis have been excluded. Such material does not, of course, exist and one can only hazard guesses as to what it might be like from the approximations to it that are available.

There are only two populations from our five that need be considered. Population C is close to the ideal except that it is confined to working miners. Population E includes ex-miners but is not so satisfactory as regards sampling, definition of population, or exclusion of other diseases. The two are compared in Fig. 13. (The age groups have been combined as the age distribution is similar, see Table 4.) The results from Population E would unfortunately support one theory and that of C the other, and there is no method of deciding whether the rising E.S.R. is due to the inclusion of the ex-miners or the faulty sampling, or the inclusion of cases with other diseases likely to raise the E.S.R.

We might possibly suggest that the prevalence of upper respiratory infections is associated with simple pneumoconiosis and that only the most heroic methods of exclusion can get rid of this association, and furthermore, that the theoretical and practical interest is so slight that it does not justify the hard work involved.

Relationship with Gamma Globulin Measurements.—Estimates of gamma globulin in Kunkel tests were made by Dr. Kayser of the Welsh National School of Medicine on the majority of populations A and C. The results are shown in Table 7. It will be seen that on the average the values are higher for P.M.F. but the wide scatter discouraged us from further investigations on these lines.

Relationship with Social Disability.—The social consequences of pneumoconiosis were reviewed by Hugh-Jones and Fletcher (1951). They pointed out how serious the problem of unemployment was for the ex-miner with pneumoconiosis, owing to his disability on the one hand and his suspension from his trade on the other. The problem was re-investigated in greater detail during the first Rhondda Fach survey. Fig 14 shows an analysis based on the

TABLE 7

AVERAGE VALUE AND SCATTER OF GAMMA GLOBULIN IN THE VARIOUS AGE-RADIOLOGICAL GROUPS IN THE TWO POPULATIONS

Population	Age Group	Radiological Categories				
		0	1–2	3	A	B.C.D.
A	± 35	7·3 (7·1–7·5)	5·4 (3·5–6·7)	5·1 (1·6–9·1)	11·6 (5·7–20·7)	10·4 (3·8–18·2)
	± 45	2·4 —	5·8 (1·9–12·9)	8·3 (3·7–14·0)	7·2 (4·1–9·0)	9·4 (4·0–18·7)
	± 55	4·1 —	7·2 (4·0–12·7)	7·4 (2·4–10·2)	5·8 (3·5–9·8)	7·1 (3·1–11·0)
C	± 35	5·0 (2·8–8·6)	5·0 (2·6–7·5)	5·5 (2·7–9·5)	4·8 (4·5–5·4)	
	± 45	5·7 (3·3–14·0)	4·2 (2·6–6·9)	3·8 (2·0–6·3)	4·9 (2·9–6·5)	
	± 55	5·4 (3·2–9·2)	5·6 (2·2–8·0)	5·0 (2·6–9·6)	6·8 (3·9–9·1)	

FIG. 14

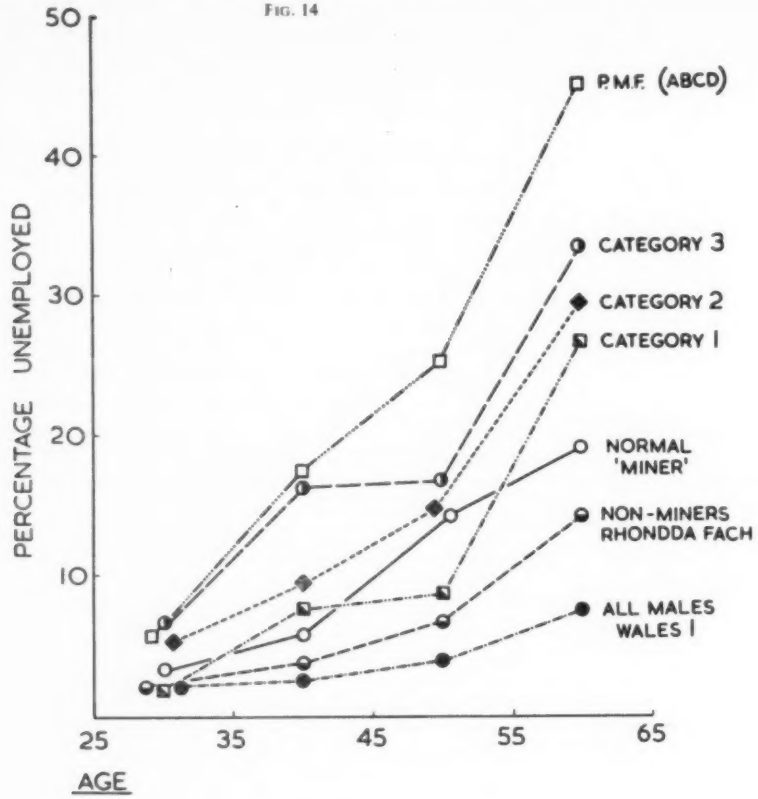
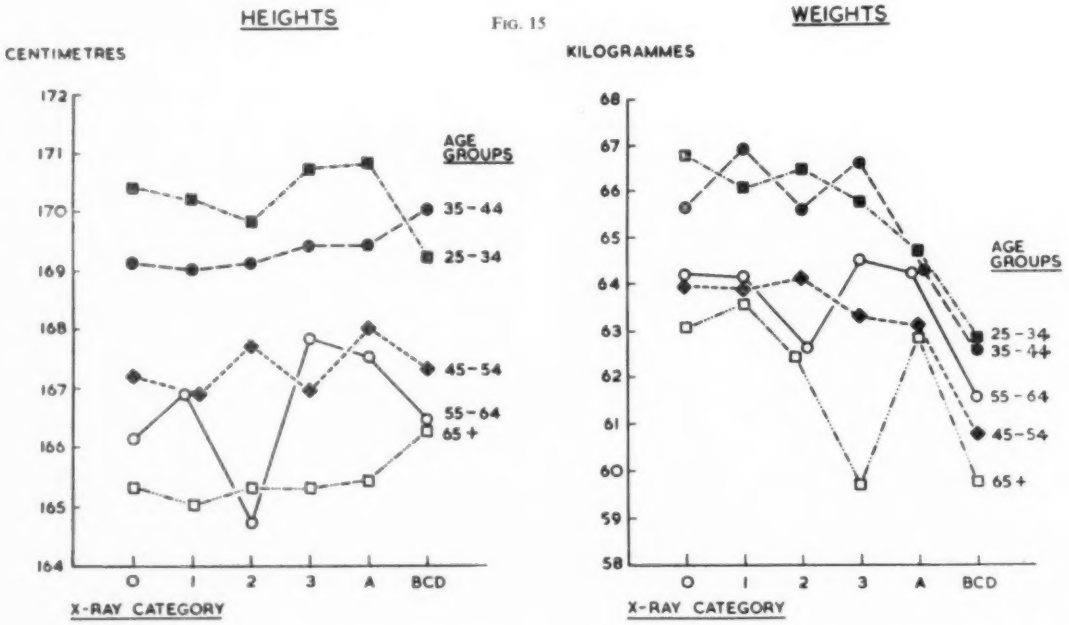


Fig. 14.—Miners, ex-miners, and non-miners by age, radiological category, and unemployment.

FIG. 15.—The average heights and weights of miners and ex-miners in the Rhondda Fach analysed by age and radiological category.

FIG. 15



industrial histories of the miners and ex-miners interviewed and radiographed during the scheme. It shows that there is a very definite empirical relationship between radiological category and percentage unemployment if due allowance is made for age. It is, however, uncertain whether the radiological category is connected with unemployment through " disability " or " suspension ", or both.

Relationship with Height and Weight.—Fig. 15 shows the relationship between age-radiological category and height amongst the miners and ex-miners in the Rhondda Fach. The usual decline with age is seen in all radiological groups. There is no significant difference between the different radiological groups. Gilson and Hugh-Jones (1955) found that stem height and radiological status were related, the higher radiological groups having lower average stem heights, but we are unable to confirm this in our data for heights. Fig. 15 also shows the relationship between age, radiological category, and weight on the same population. It demonstrates that the more advanced stages of complicated pneumoconiosis cause a very definite loss of weight.

Conclusions

All the evidence we have assembled suggests that the radiological prevalence of pneumoconiosis, in comparison with other abnormalities, is high—although probably not higher than in comparable areas in other countries. It must, however, be remembered that the prevalence has been measured in purely radiological terms. Before considering this as giving information about the size of the problem one must consider the relationships established between radiological category and other biological characteristics.

We are now in a position to say that simple pneumoconiosis is unassociated with loss of weight or serious loss of expectation of life; probably unassociated with a raised E.S.R., and associated with only slight pulmonary disability. It is, however, probably associated, as far as categories 2 and 3 are concerned, with an increased liability to develop P.M.F. In the absence of P.M.F., the high prevalence of simple pneumoconiosis would not represent a serious problem.

All the evidence, on the other hand, suggests that P.M.F. is a serious, chronic, slowly progressive disease, associated on the average with loss of weight, raised E.S.R., pulmonary disability, an increased tendency to develop a positive sputum, and a shortened expectation of life. It is therefore only correct to pay more attention to the prevalence of P.M.F. than to that of simple pneumoconiosis.

It is, however, a sad fact that the prevalence of P.M.F. is far too high. It can be looked at from three different points of view. It is in the first place an awful warning as to what happens when industrial processes continue for many years without adequate medical control. Secondly, it is a challenge to preventive medicine. The measures suggested to prevent this disease are better discussed with the factors influencing the attack rate of P.M.F., but in summary it can be said here that the possible approaches might include some of the following:

(1) The reduction of dust concentration in the mines to such a level that only a small percentage of miners exposed to this concentration throughout their working lives would be likely to develop sufficient simple pneumoconiosis to be at risk as regards the development of P.M.F.

(2) A system of routine radiography which would remove miners from further dust exposure likely to cause progression of simple pneumoconiosis after category 1 is reached. This would have the additional advantage of controlling tuberculosis in the collieries.

(3) The reduction of tuberculous infectivity in mining areas (Cochrane *et al.*, 1955).

Another point of view is the " tuberculosis " one. Many of us have hopes of eliminating tuberculosis from this country in the near future. There are many obstacles in the way, but one of them will be the number of cases of P.M.F. in some mining areas, combined with their tendency to develop positive sputum. This will call for constant vigilance by the chest clinics in the mining areas.

Summary

In radiological surveys of coal-miners the Pneumoconiosis Research Unit has used a classification consisting of three categories of simple pneumoconiosis and four of progressive massive fibrosis (P.M.F.). It has proved to be a reliable index of dust exposure and to give some indication of pathological change. Progressive massive fibrosis is a sinuously disabling disease which may shorten life, while simple pneumoconiosis causes slight disability.

The underground populations of 12 British collieries had prevalences of radiological abnormality ranging from 60% to 20%. At eight of these collieries (in Wales) the surface populations had prevalences ranging from approximately 40% to 20%. There is some indication that the prevalences of pneumoconiosis among surface and underground workers in four Rhondda Fach collieries were similar to prevalences in French collieries. Among Belgian coal-miners there was a relatively high

percentage of simple pneumoconiosis with a low prevalence of P.M.F.

A comparison of the prevalence of pneumoconiosis among the younger miners and ex-miners radiographed in the Rhondda Fach in 1950-51 and 1953 suggests that there has been a true fall in the attack rate of simple pneumoconiosis and P.M.F. While patients with P.M.F. have on the average higher enythrocyte sedimentation rates (E.S.R.) than those with simple pneumoconiosis, there is no reliable evidence that there is a regular and significant increase in the average E.S.R. with radiological category in the simple form of the disease.

The more advanced stages of P.M.F. are shown to be associated with a definite loss of weight.

There is a definite relationship between radiological category and percentage unemployment, but it is uncertain whether this is due to physical disability or the operation of compensation Acts, or both.

Since P.M.F. only develops upon advanced simple pneumoconiosis it could be prevented by reducing dust concentrations which are responsible for producing advanced simple pneumoconiosis. Its attack upon men who already have simple pneumoconiosis could be prevented by routine radiography and by reducing tuberculous infectivity in mining areas.

In work of this nature it is impossible to acknowledge personally all the assistance that has been given. It is, however, a pleasure to acknowledge the great help we have had from the officials of the National Coal Board and members of the National Union of Mineworkers in all the areas concerned, the Ministry of Fuel and Power, the Ministry of Pensions and National Insurance, the people of the Rhondda Fach, the staff of the Pneumoconiosis Research Unit, and all those who were at various times members of the epidemiological and radiographic teams.

REFERENCES

Appelman, A. C. (1949). *Ned. T. Geneesk.*, **93**, 3703.
Balgairies, E. (1952). Personal communication.
Belayew, D. (1950). *Rev. méd. minière* (No. 12), **3**, 160.
Birkelo, C., Chamberlain, W. E., Phelps, P., Schools, P., Zacks, D., and Yerushalmy, J. (1947). *J. Amer. med. Ass.*, **133**, 359.
Boehme, A. (1933). *Beitr. Klin. Tuberk.*, **84**, 119.
—— (1950). Personal communication.
Bruusgaard, A. (1950). *Nord. Med.*, **43**, 676.
Caplan, A. (1947). *Silicosis Pneumokoniosis and Dust Suppression in Mines; Proc. Conf. Inst. Mining Engineers, and Instn Mining and Metallurgy*, p. 33. London.
Carpenter, R. G., and Cochrane, A. L. (1956). *British Journal of Industrial Medicine*, **13**, 102.
——, ——, Gilson, J. C., and Higgins, I. T. T. (1956). *British Journal of Industrial Medicine*, **13**, 166.
——, ——, Miall, W. E., and Jarman, T. F. (1956). *Tubercle* (*Lond.*), **37**, 225.
Cazamian, P. (1947). Private circulation.
Champeix, J., and Thevenoux, R. (1949). Private circulation.
Clarke, W. G. (1953). *Radiography*, **19**, 224.
—— (1955). *Beitrage zur Silikose-Forschung. Bericht üder das "Silikose-Symposium, 1955"*, page 54, Bochum.
Clayson, C., Frew, H. W. O., McIntosh, D. G., McWhirter, J. G., McKinlay, P. L., and Stein, L. (1955). *Brit. J. Tuberc.*, **49**, 81.
Cochrane, A. L. (1954a). *Brit. med. Bull.*, **10**, 91.
—— (1954b). *Brit. J. Tuberc.*, **48**, 274.
——, and Carpenter, R. G. (1956). *British Journal of Industrial Medicine*, **13**, 177.
—— Chapman, P. J., and Oldham, P. D. (1951). *Lancet*, **1**, 1007.
——, Cox, J. G., and Jarman, T. F. (1952). *Brit. med. J.*, **2**, 843.
——, ——, —— (1955). *Ibid.*, **1**, 371.
——, Davies, I., and Fletcher, C. M. (1951). *British Journal of Industrial Medicine*, **8**, 244.
——, and Garland, L. H. (1952). *Lancet*, **2**, 505.
——, Jarman, T. F., and Miall, W. E. (1956). *Thorax*, **11**, 141.
——, and Miall, W. E. (1956). *Brit. med. J.*, **1**, 1193.
Craw, J. (1937). *Tubercle* (*Lond.*), **19**, 8.
Dahlberg, G. (1948). *Nord. Med.*, **38**, 985.
Davies, I., Fletcher, C. M., Mann, K. J., and Stewart, A. (1949). Proc. 9th Int. Congr. on Industr. Med., 1948, p. 773. London. Wright, Bristol.
Declercq, G., Balgairies, E., Flouquet, M., and Morel, A. (1949). *Rev. méd. minière.*, **2**, No. 7, p. 9.
Deeny, J., Walsh, N. F., and Conran, M. M. (1952). *Irish J. med. Sci.*, p. 193.
Fletcher, C. M. (1955a). *A.M.A. Arch. industr. Hlth*, **11**, 17.
—— (1955b). *Ibid.*, **11**, 29.
——, Mann, K. J., Davies, I., Cochrane, A. L., Gilson, J. C., and Hugh-Jones, P. (1949). *J. Fac. Radiol.*, **1**, 40.
Flinn, R. H., Seifert, H. E., Brinton, H. P., Jones, J. L., and Franks, R. W. (1941). *Publ. Hlth Bull.* (*Wash.*), No. 270.
Foubert, P. (1948). *Rev. méd. minière.*, **1**, No. 1, p. 4.
Garland, L. H. (1949). *Radiology*, **52**, 309.
—— (1950). *Amer. J. Roentgenol.*, **64**, 32.
Gilson, J. C., and Hugh-Jones, P. (1955). *Spec. Rep. Ser. med. Res. Coun.* (*Lond.*), No. 290.
Hart, P. D'A., and Aslett, E. A. (1942). *Ibid.*, No. 243.
Heimann, H. (1946). *Occup. Med.*, **2**, 470.
Higgins, I. T. T., Oldham, P. D., Cochrane, A. L., and Gilson, J. C. (1956). *Brit. med. J.*, in press.
Hugh-Jones, P. (1952). *Symposium on Coal Miners' Pneumoconiosis.* Elkins, West Virginia.
——, and Fletcher, C. M. (1951). *Med. Res. Coun.*, Memo. No. 25.
McCallum, R. I. (1952). *British Journal of Industrial Medicine*, **9**, 99.
——, and Browne, R. C. (1955). *Ibid.*, **12**, 279.
Mann, K. J. (1951). *Thorax*, **6**, 43.
Martin, E., and Roche, L. (1944-45). *Arch. Mal. prof.*, **6**, 67.
——, —— (1945). *Bull. Acad. Méd.* (*Paris*), **129**, 582.
Mechelen, van V. (1951). *Verh. kon. Akad. Geneesk. Belg.*, **13**, 1.
Nadiras, P., Batique, L., and Michot, R. (1948). *Rev. méd. minière.*, **1**, No. 4, p. 32.
Oldham, P. D. (1953). *Trans. Ass. industr. med. offrs*, **3**, 218.
Perret, A., and Mattei, J. (1947). *Arch. mal. prof.*, **8**, 196.
Reichmann, V. (1949). *Beitr. Silikose-Forsch.*, No. 1.
Roach, S. A. (1953). *British Journal of Industrial Medicine*, **10**, 220.
Saita, G. (1945). *Med. d. Lavoro*, **36**, 59.
Sayers, R. R. (1936). *Publ. Hlth Bull.* (*Wash.*), No. 221.
Schmidt, H. (1949). *Beitr. Silikose-Forsch.*, No. 2, p. 35.
Sen, P. K. (1937). *J. industr. Hyg.*, **19**, 225.
Stewart, A. (1948). *British Journal of Industrial Medicine*, **5**, 120.
Stocks, P. (1949). *Sickness in the Population of England and Wales in* 1944-1947. General Register Office, Studies on Medical and Population Subjects, No. 2. H.M.S.O., London.
Theodos, P. A., and Gordon, B. (1952). *Amer. Rev. Tuberc.*, **65**, 24.
Tortori-Donati, B. (1947). *Med. d. Lavoro*, **38**, 151.
Watkins, J. T. (1950). *Med. Offr*, **84**, 53.
Worth, G., Schiller, E., and Dickmans, H. (1951). *Beitr. Silikose-Forsch.*, No. 14, p. 35.
Yerushalmy, J., Harkness, J. T., Cope, J. H., and Kennedy, B. R. (1950). *Amer. Rev. Tuberc.*, **61**, 443.
Zorn, O. (1949). *Beitr. Silikose-Forsch.*, No. 2, p. 1.

Brit. J. industr. Med., 1956, **13**, 251.

PNEUMOCONIOSIS OF KAOLIN WORKERS

BY

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Kaolin, or china clay, is an important raw material which is exploited industrially in Cornwall, England, in Georgia, U.S.A., and in several other localities. In the past it has been assumed that exposure to kaolin dust does not lead to disabling pneumoconiosis, but over the past 10 years the experience of one of us in Cornwall has suggested that this may be incorrect. Difficulty has always been experienced, however, in obtaining an occupational history uncomplicated by periods in other work carrying a silicosis risk, such as metal mining, granite dressing, or the like.

In this communication, clinical and radiological observations of several cases will be described. Three of these men had worked at the same place in Cornwall, and had been engaged in drying and bagging disintegrated china clay. One of them came to necropsy in 1950, and the pathological findings and analyses of the mineral contents of the lung are given. Similar data are also given for a kaolin worker from Georgia, U.S.A.

Working Conditions

Winning of china clay in Cornwall is generally carried out wet, and there is very little dust produced until the refined clay is dried and shipped. Until about 1920, the clay was dried in open sheds to a moisture content of 15 to 20%, and although some steam and dust were produced in these sheds, dust concentrations were not very high. Since that time, however, there has been a tendency to produce drier clay by the technique of filter pressing. Under these conditions much higher dust concentrations exist, especially in the drying plants where fine clays are disintegrated after drying and filled into bags. Three of the men described in the following case histories had worked in a plant of this type for over 20 years. Very high dust concentrations are also found in the holds of ships loading china clay.

Clinical, Radiological, and Pathological Observations

Case 1.—A man (C. P.) aged 44 years was first seen on March 15, 1949, complaining of shortness of breath, at rest as well as on activity, for four years past; some tight feeling across both pectoral regions; cough, especially at night, with thick white sputum (reputed to be as much as a teacupful per 24 hours), never bloody. He had lost weight from 182 lb. to 157 lb. and he noted some weakness and tiredness. There was no relevant past history of illness and no family history of respiratory disease.

He left school at 14 years. He was a kettle-boy in clay works, doing odd jobs for two years, and for the past 28 years has worked at a kaolin mill, bagging the finest pharmaceutical grade of kaolin powder.

On examination he was in poor general condition; he was dark skinned, slightly cyanosed, showed no finger clubbing, and was easily dyspnoeic on slight exertion.

The chest expansion was only 1¼ in. by measurement. The signs were those of emphysema, but no rales. There was no hypertension and no clinical evidence of cardiac disease. Examination in other respects was negative. His haemoglobin was 108% and the white cell count was normal. The E.S.R. was 19 mm. in one hour. Sputum was requested but was not obtained.

His radiograph at that time showed well-marked nodulation of silicotic type, with coalescence of the nodules in several areas. Emphysema was present.

He was seen again in April and June of 1949, and no new physical signs were noted, though his respiratory disability had increased, and the dyspnoea had become distressing. He stated that three of his mates working in the same process had died, at ages about 55, 50, and 31, " all of them went short of breath ".

Enquiry about the workmates mentioned above did not reveal any conclusive evidence that they had had pneumoconiosis; they had been considered to have bronchitis or asthma but no radiological or pathological evidence was obtainable.

When seen in March, 1950, his weight had fallen to 144 lb. and his dyspnoea was very distressing. He had been in bed most of the preceding four months.

His general condition was much poorer but he was not markedly toxaemic. His respirations were 44 per minute. Chest movement was very small, there was no gross dullness anywhere, the breath sounds were harsh over the front of the thorax, and broncho-cavernous over both upper zones there. No moist sounds were heard anywhere. His sputum specimens were spoiled in transit.

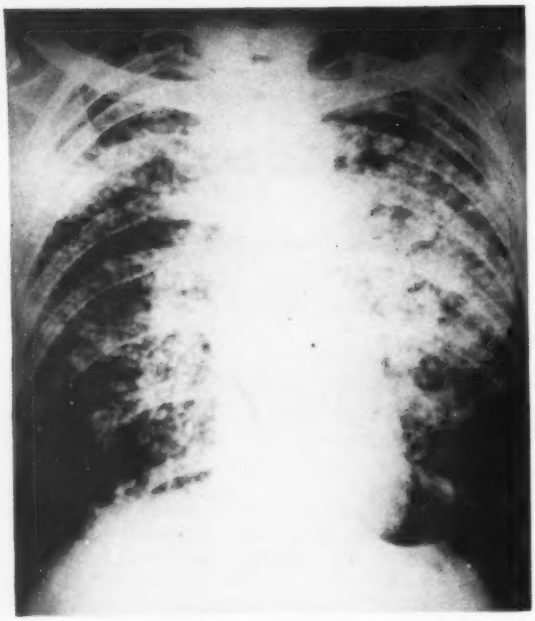

FIG. 1.—Radiograph of Case 1 (C. P.).

The E.S.R. had risen to 36 mm. in one hour. There had been a change in the radiological appearances, multiple areas of coalescent shadowing being present throughout the greater part of both lung fields (Fig. 1). In the left apex there was a rounded translucent area suggestive of cavitation. A diagnosis of silico-tuberculosis was made.

He died on April 19, 1950, and a necropsy was performed. There was obvious emphysema when the thorax was opened. Both lungs were densely adherent, in the upper portions especially. The pleura showed the appearances characteristic of silicosis. The hilar glands were dark, hard, and fibrosed.

Large thin sections of the left lung showed grey nodules, most of which were about 1 to 4 mm. in diameter, but some up to 6 mm. Some of these were discrete but many were confluent. They were present in greatest numbers in the upper three-quarters of the lung and only the lingula was free of nodules. The grey colour of the lesions was unlike that seen in any other form of pneumoconiosis. There were areas of caseation throughout the lung with cavity formation several centimetres across at the apex and several cavities of about 1 cm. across in the lower part of the upper lobe and in the lower lobe. In the lower half of the lower lobe the tuberculosis had an acinose formation with grey nodules in the centres and paler areas of caseation around these centres.

The right lung showed great thickening of the pleura. The hilar glands were enlarged, grey, and caseous. There were nodules up to 6 mm. in diameter throughout the lung, except in the lower half of the middle lobe. These were grey and circumscribed, most were discrete, some were confluent.

There was extensive caseous tuberulosis throughout the lung with acinose formation in some parts.

Histology.—Most of the nodular lesions showed caseous tuberculosis, but some nodules had hyaline fibrosis which may have antedated the tuberculosis and been produced by the dust. In many respects they simulated classical silicotic lesions. In the many histological sections taken there were very few dust foci unaffected by tuberculosis, but from the occasional ones seen it would appear that the dust had been causing hyaline fibrosis (Fig. 2). Against this view is the fact that in places in the hilar glands where there was a great deal of dust there was little fibrosis. There was one hyaline fibrous nodule in a lymph node, but this is not an uncommon finding where inert dust is present in a gland, and was presumably a focus of healed tuberculosis.

The analysis of the lung dust of Case 1 is given later.

Case 2.—A man (W. K.) aged 67 complained of productive cough for " several years ", with a moderate quantity of yellowish sputum, never bloody. He complained of shortness of breath recently, but no pain. When seen in 1952 he was rather thin; of average appearance for his age, not toxaemic, and with no finger clubbing. The physical signs were those of well-marked emphysema, with a few moist sounds at the right base. Examination of the cardiovascular and other systems was negative.

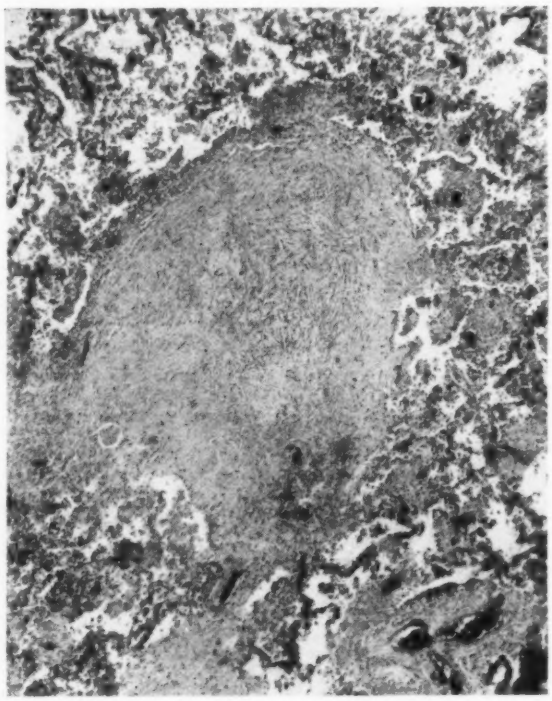

FIG. 2.—Nodule of fibrosis in Case 1 (C. P.) × 55.

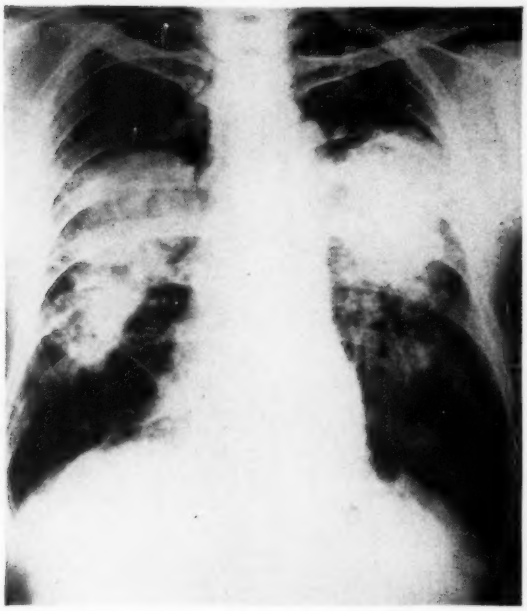

FIG. 3.—Radiograph of Case 2 (W. K.).

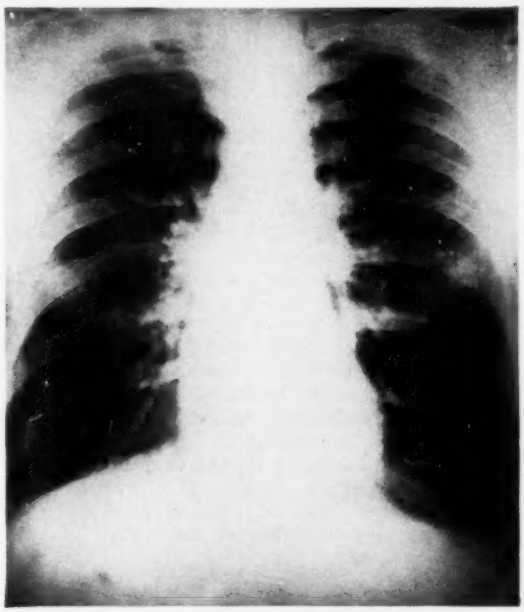

FIG. 4.—Radiograph of Case 3 (E. T.).

There was no relevant past history of illness, and no family history of respiratory disease.

He had spent practically all his working life in the china-clay industry; he had never worked underground, nor with granite or china stone, and for about 30 years past had bagged finely divided kaolin in the mills.

His radiograph (Fig. 3)* showed a low diaphragm and considerable emphysema. In addition, large areas of massive fibrosis were seen on both sites, involving the apical segments of both lower lobes; these were well defined and discrete in outline, and exactly resembled the radiological appearances seen in the progressive massive fibrosis of coal-miners. In addition there was an increased linear striation throughout both lung fields. Tomographs showed no evidence of cavitation. The sputum was repeatedly negative for tubercle bacilli.

The corrected vital capacity was 1,833 ml. Bronchoscopy showed no evidence of neoplasm and this conclusion has been supported by his subsequent progress. He has become increasingly disabled by shortness of breath; in March, 1955, he was unable to do any work. His disability was certified as 100% by the Pneumoconiosis Medical Board.

Case 3.—A man (E. T.) aged 44 was referred in March, 1953, on account of shortness of breath and a tight feeling in the chest in the mornings for some years past. He had been regarded as a case of bronchial asthma.

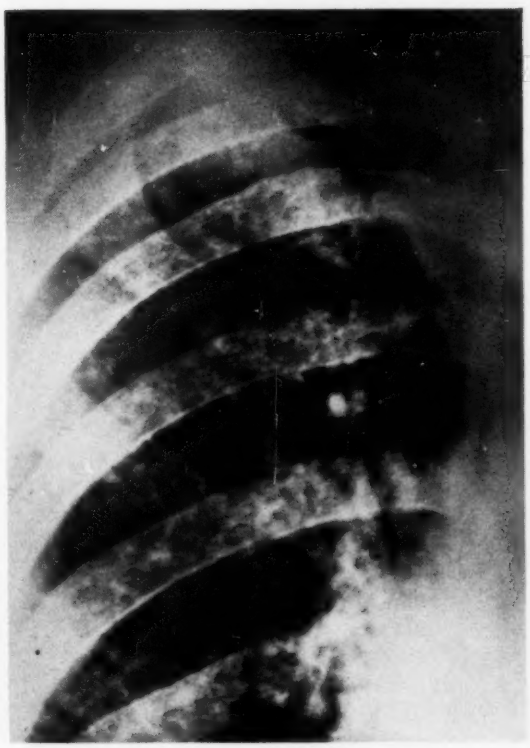

FIG. 4a.—Detail of right upper zone in Case 3 (E. T.).

* We have recently discovered another case, with quite similar radiological appearances, but not considered to have been under observation long enough for inclusion at this date.

He had left school at 14 years and worked in the china-clay industry all his life, as a tip-boy for one year, as a general labourer in the pits for five years, and in the same mill as C. P. and W. K. for 24 years, mostly bagging fine milled kaolin powder. He had joined the Army in the recent war, but was invalided out after two months " on account of his chest ".

He stated that he was only just able to do his job, but had not had any long absence from work. There was no history of other significant past illness. He was a man in fairly good general condition, slightly cyanosed, with a chest held in the inspiratory position, poor air entry, and physical signs of marked bronchospasm.

The radiograph (Fig. 4) showed diffuse nodular mottling typical of pneumoconiosis, with considerable accentuation of the bronchovascular markings. There was no evidence of focal secondary infection.

He has remained under periodic out-patient observation ever since, and shows no general deterioration. There is much variation in the degree of bronchospasm. His disability has been assessed at 30% by the Pneumoconiosis Medical Panel. He is now occupied in the same works at a light job carrying no dust risk.

FIG. 5.—Detail of left upper zone in Case 4 (N. C.).

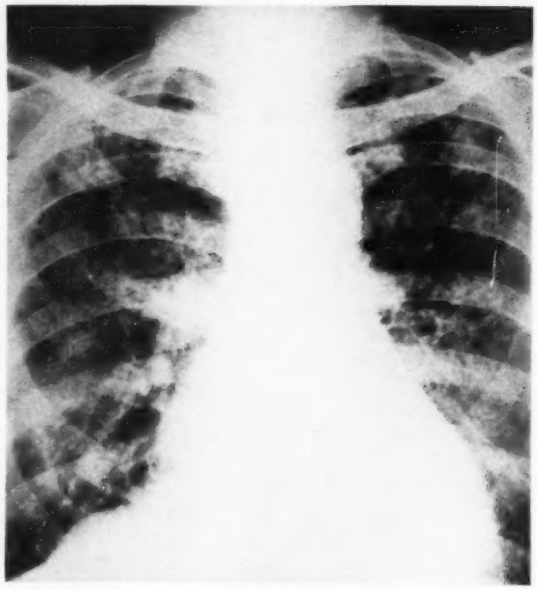

FIG. 6.—Radiograph of Case 5 (A. L.).

Case 4.—A man (N. C.) aged 39 was first seen in June, 1952, in the course of contact investigation of a case of tuberculosis in his household. He was, and still remains, entirely free from symptoms. He had had pneumonia in infancy; there was no relevant family history save as above.

He left school aged 15, worked in agriculture for four years, as a baker for four years, as a boat-hand two years, as a kettle-boy in clay works two years. He was in the Royal Navy for six years, followed by 14 years at the clay works, mainly engaged in shovelling bulked dried clay into bags, which he stated was a dusty job.

He was a healthy and well-built man, and showed no abnormal clinical physical signs. The radiograph showed uniform fine miliary mottling throughout both lung fields, with well-marked calcification at the left hilum. The sputum was persistently negative for tubercle bacilli. The skin tuberculin test was positive.

Follow-up over the succeeding two years has shown no progression in the radiological appearances, which are unchanged, and this has been considered sufficient to exclude any infective cause for the radiological appearances.

Case 5.—A man (A. L.) aged 73 was first seen in November, 1954, complaining of an attack of right axillary pain, of pleuritic type, and a single small haemoptysis. He had some cough and scanty white sputum, and physical signs of emphysema only. He denied habitual cough, and stated that normally he has no more shortness of breath than could be expected at his age. The cough and pain disappeared in a few weeks and there was no further haemoptysis. There were no definite signs or symptoms of cardiovascular origin.

He now has no cough, no pain, no shortness of breath beyond the average for his age, and no cardiac symptoms.

He worked at open limestone quarries for 12 years, then for 20 years bagging milled china-clay by hand, filling brown paper bags with a hand shovel, in a chamber through whose ceiling the milled product was discharged from a mill on the floor above. (This was a far more dusty occupation than any likely to be encountered under present-day working conditions.) He was subsequently foreman in charge of loading china-clay into trucks (moderate or negligible dust exposure) until retirement two years previously. His retirement was due to his age and anxiety about his health following the so-called heart attack four years previously rather than to respiratory disability.

Physical examination showed him to be normal or better than average for a man aged 73.

The radiograph (Fig. 6) showed generalized small discrete nodular mottling, with increase of the root shadows and of the lung markings; there was some coalescence of the opacities in the upper zones, but no definite massive fibrosis.

Case 6.—A man (L. M.) aged 64 was first seen in April, 1954, complaining of cough and shortness of breath. He was able to walk any distance on level ground but was handicapped uphill. The cough had been worse during the previous 12 months, but he had had it for years. Sputum was white, scant, never bloody. There was no relevant history of past illness nor any family history of any respiratory disease.

He worked for 43 years in the docks, loading cargo in the holds of small vessels. Most of the time was spent loading china clay, and it is a very dusty job. He had, however, loaded or unloaded cargoes of coal from time to time also, and in his early life worked for three years as a timberman in a coal-mine in South Wales. He never worked at the coal-face. He estimated the amount of coal working he had done at less than a quarter of his work. (Enquiry at the docks showed that about three or four cargoes of coal had been handled annually, and 20 or more of clay weekly.)

FIG. 7.—Radiograph of Case 6 (L. M.).

He was a healthy-looking man with no anaemia or cardiovascular cause for his breathlessness. Clinically, there was probably some emphysema, and fine rales were audible at both bases. The radiological appearances (Fig. 7) showed considerable accentuation of the bronchovascular markings in the lung fields and definite nodular mottling. His corrected vital capacity was 2 litres.

This case illustrates the difficulty in Cornwall of finding a completely " pure " history of exposure to china-clay dust alone. We have seen two or three other cases in which similar or more marked radiological appearances (and clinical disability also) were present, and the history was preponderantly of exposure to china-clay, but also included a year in tin-mining, a year gold-mining in the U.S.A., or the like. Details of these cases are not quoted, for it is felt that these other exposures detract from their interest.

Lung Dust Analyses

In Case 1 (C. P.) the dried right lung weighed ca 115 g. A representative sample of powdered lung tissue was ashed at 380° C and the ash extracted with cold 2N HCl. The lung dust produced in this way was 8·2% of the dried lung, corresponding to perhaps 18 g. of dust in both lungs.

Radiological diffraction diagrams of kaolin from Cornwall and of the lung dust are shown in Figs. 8a and 8b. They indicate much kaolin, little mica, and 1% or less of quartz; electron micrographs (Fig. 9) show the material to be similar to commercial china clay from Cornwall, although there were areas seen in the photograph where the material appeared to be attacked or altered.

Partial chemical analyses of the lung dust and of a sample of kaolin from Cornwall gave:

	Lung Dust	Kaolin
SiO_2	52%	46·5%
Al_2O_3	30%	39·6%
Ignition loss	15%	13·9%

These figures show an excess of silica, which was certainly not present in the form of quartz. A quantitative mineral determination by an internal standard radiological diffraction technique (Griffin, 1954) showed 50% of kaolin and 10 to 20% of mica. This is in agreement with the chemical results, except for an excess of SiO_2 of the order of 15 to 20% of the sample.

Amorphous silica is much more easily soluble in dilute alkali than the silica of most silicate minerals or quartz. Repeated extractions with hot 5% NaOH

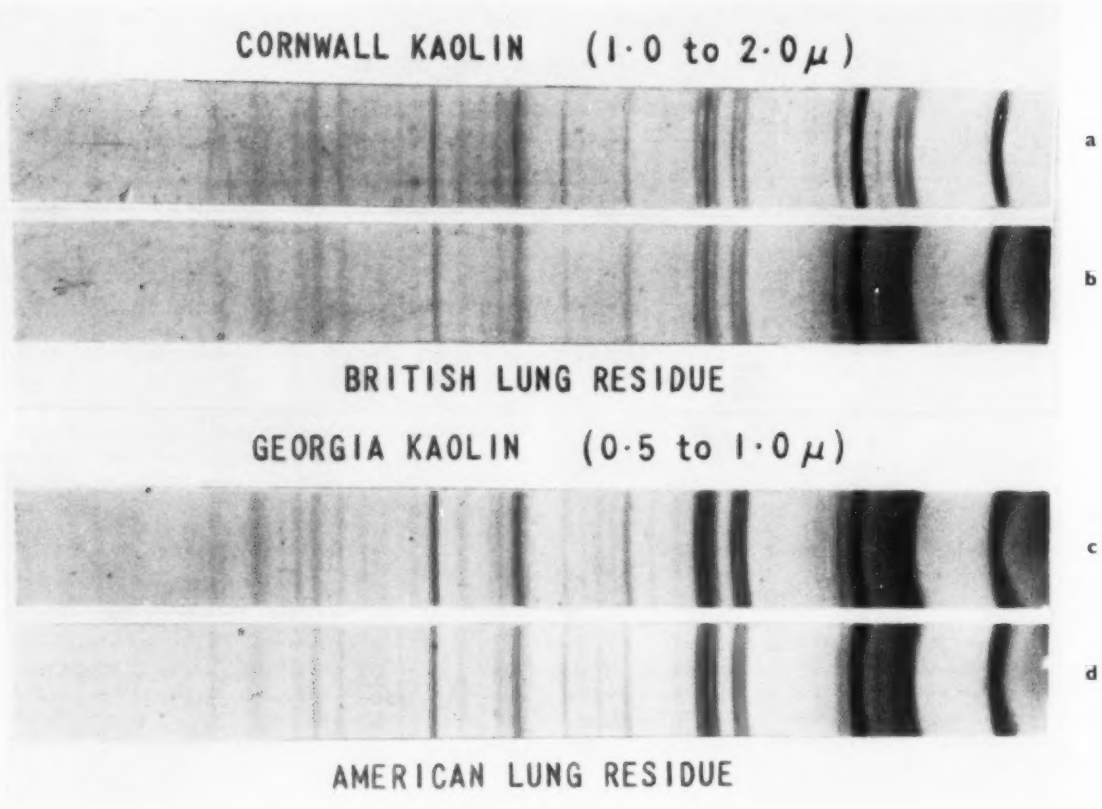

FIG. 8.—Radiological diffraction diagrams:—
(*a*) Kaolin from Cornwall.
(*b*) Lung residue of Case 1 (C. P.).
(*c*) Kaolin from Georgia, U.S.A.
(*d*) Lung residue of Case 7 (W. M.).

for half a minute were therefore made of the lung residue and of a kaolinite sample of similar size, 1 to 2 microns, and the SiO_2 in solution was determined colorimetrically.

The results are shown in Table 1.

TABLE 1
SILICA DISSOLVED FROM LUNG DUST AND FROM KAOLIN BY NaOH

No. of Extraction	Percentage Lung Residue	Percentage Kaolin
1	14·6	0·33
2	1·3	0·3
3	0·45	0·03
4	0·51	—
5	0·36	—

It appears from these tests that 15% of the isolated lung dust was present as amorphous silica, the remainder being mainly kaolinite and some mica. There are two possible explanations for the presence of amorphous silica: (1) That the man was exposed to sodium silicate dust which is used to deflocculate clay suspensions. The amorphous silica may be the residue of the sodium silicate. However, sodium silicate forms only a very small percentage of the clay and there is said to be no dust hazard from it. (2) That the kaolin may have been attacked in the lung and a certain amount of alumina removed, leaving a corresponding amount of amorphous silica with the remaining kaolin. Treatment with cold 2N hydrochloric or sulphuric acid does not attack kaolin, and it requires hot concentrated sulphuric acid to remove appreciable amounts of alumina. It will be seen that neither explanation appears satisfactory.

Case 7.—Through the courtesy of Dr. R. W. Edenfield we received for analysis a sample of fibrosed lung tissue of a (Negro) kaolin worker (W. M.) from Georgia, U.S.A., with some notes, from which the following are excerpts:

W. M., who died aged 44, in 1953, worked for over 20 years as a labourer in a kaolin plant and had never been employed elsewhere. He had worked for several

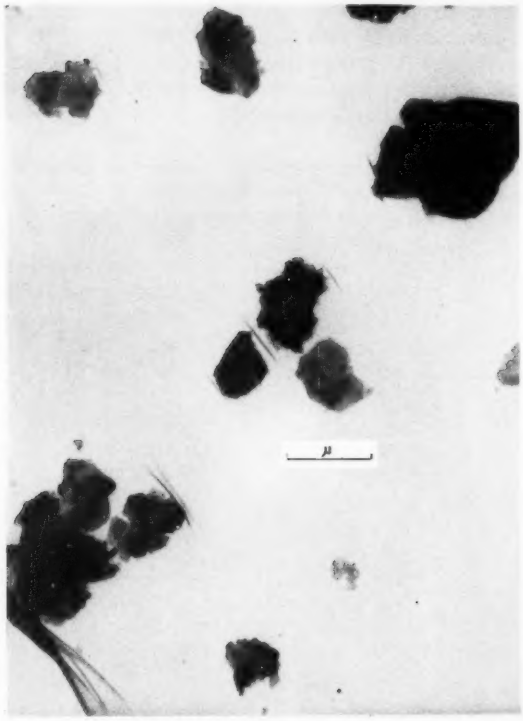

FIG. 9.—Electron micrographs of lung residue from Case 1 (C. P.).

years in the bagging and loading area, which is rather dusty. In 1946, a radiograph showed "moderately advanced pneumoconiosis" and in 1948 he complained of shortness of breath. A radiograph taken a few days before death is shown in Fig. 10. W.M. died in 1953

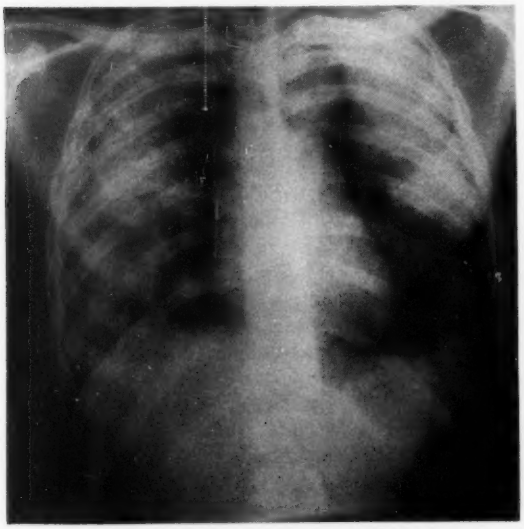

FIG. 10.—Radiograph of Case 7 (W. M.).

and the following is an excerpt from the necropsy report:

"The lungs are converted into stony hard masses. Less than a quarter of the lung volume is crepitant. The remainder is cartilage-hard and fibrous and cuts with a gritty sound. There is a pneumonic consolidation within parts of the right lower lobe. There is considerable pleural thickening about the apices on both sides."

FIG. 11.—Section of fibrosed area with adjacent area of nearly normal lung. Haematoxylin and eosin × 25 (Case 7, W. M.).

Histological examination of a fibrosed part of lung tissue (Fig. 11 and 12) was done by Professor C. V. Harrison, of the Postgraduate Medical School of London, who commented as follows:

"The specimen consists of a part of a nodule together with a fringe of surrounding lung. The nodule is grey with a paler edge and it is not nearly as hard as a silicotic or fibrotic nodule.

The nodule consists of a rather loose framework of reticulin and collagen in which are embedded masses

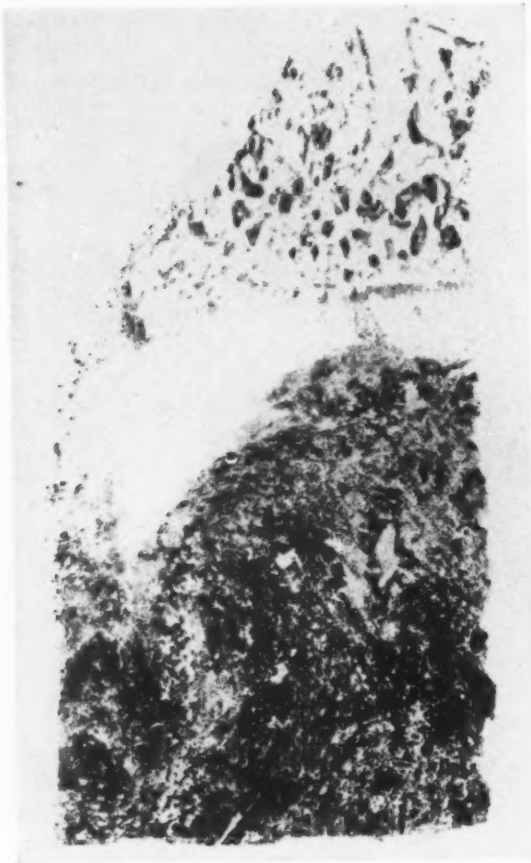

FIG. 12.—Microincinerated serial section of Fig. 11.

of kaolin. The whole nodule appears to be necrotic and its vessels are all obliterated by endangeitis. No acid-fast bacilli were seen but the nodule contains a fungal mycelium.

This is a remarkable lesion. It is quite unlike a silicotic lesion but it does bear a strong structural resemblance to the massive lesions of South Wales coal-miners."

Some of the fibrosed tissue was ashed at 380° C and the ash extracted with 2N HCl. The residue obtained was 35 to 40% of the oven-dried lung, an unusually high value.

Partial chemical analysis of the residue gave:

	Percentage Residue	Percentage Kaolin (theoretical)
SiO_2	46·5	46·5
Al_2O_3	40	39·6
Ignition loss	12	13·9

Radiological diffraction analysis showed a strong kaolinite and a very weak anatase (TiO_2) pattern. No trace of quartz could be seen. Quantitative determination by radiological diffraction gave 98% kaolinite. Radiological diagrams of the lung dust and of kaolin from Georgia of similar size are shown in Fig. 8, and an electron micrograph of the lung dust in Fig. 13.

The residue appears to consist entirely of kaolinite.

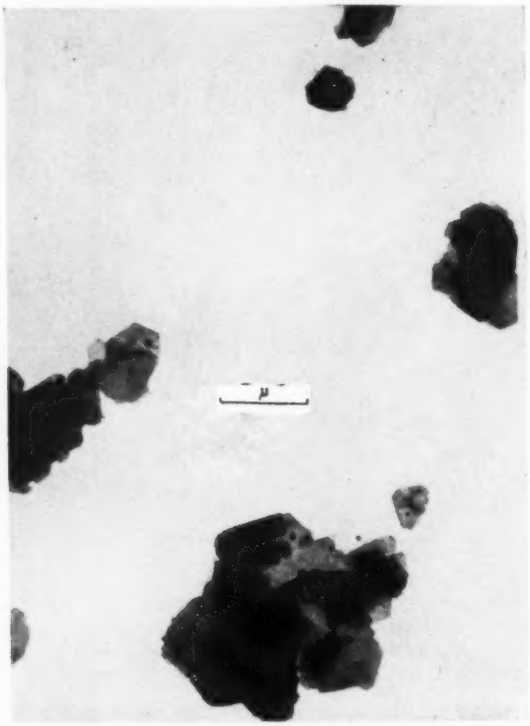

FIG. 13.—Electron micrograph of lung residue from Case 7 (W. M.).

Discussion

The possibility that kaolin could present a pneumoconiosis risk has been discussed for many years. Animal experiments (Policard and Collet, 1954; Rüttner, Bovet, Weber, and Willy, 1952; King, Harrison, and Nagelschmidt, 1948) have shown kaolin to be intermediate between an entirely inert dust such as coal and a fibrogenic dust such as quartz. An enhancement of kaolin fibrosis by dead tuberculosis bacilli has also been reported (Kettle, 1934): this finding has recently been confirmed by Attygalle, Harrison, King, and Mohanty (1955).

Cases of radiological abnormalities and shortness of breath together with an exposure history to kaolin dust in the absence of quartz have been reported by Bastenier (1950), Cavigneaux, Charles,

Fuchs, and Tara (1950). Lynch and McIver (1954) described two cases of pulmonary fibrosis from kaolin workers in South Carolina and gave the name kaolinosis to this condition.

Our clinical, radiological, and pathological observations and the two dust analyses which show comparatively large amounts of kaolin and an almost complete absence of quartz confirm that kaolin dust can cause disabling pneumoconiosis and death. In Cornwall most of the processes in kaolin production are wet and there is no dust risk except in drying, disintegrating, and bagging of fine clays. Only a small proportion of the labour force is likely to be at risk. Dry disintegration and loading of clay rocks such as are used in some other production centres might present a higher dust risk.

The type of fibrosis produced was, in Case 7 (W. M.), similar to the massive fibrosis seen in coal and haematite miners; and the radiological appearances in Case 2 (W. K.) were of this type. In Case 1 (C. P.) the fibrosis was more of the nodular hyaline type, but the lack of characteristic fibrosis in the hilar glands is a difference from that usual in silicosis.

In Case 7, there was no macro- or microscopic evidence of tuberculosis at death, nor any history of tuberculosis during adult life. In Case 1 (C. P.) there was frank tuberculosis, but it could not be decided how late during or after the dust exposure the infection had been acquired. It is therefore not possible, on the basis of this evidence, to pronounce upon the aetiological importance of tubercular infection in the production of massive fibrosis in kaolin pneumoconiosis.

Summary

Clinical and radiological observations on workers exposed to kaolin dust show that radiological abnormalities with or without marked disability occur; details of six cases are given.

Post-mortem findings show in one case large amounts of pure kaolinite dust associated with massive fibrosis, but no evidence of tuberculosis, and in the other large amounts of kaolin dust and excess amorphous silica with a more nodular type of fibrosis and progressive tuberculosis.

The amounts of kaolin found in the lungs are of the order of 20 to 40 g. in both lungs. In respect of this large amount of dust, the condition is similar to the pneumoconiosis of coalworkers and different from classical silicosis.

We are indebted to Dr. Gwynne Jenkins and Dr. J. C. Mellor for providing us with radiographs and details of two cases, and Professor C. V. Harrison for his report on the histology of one of the cases.

The paper is published by permission of the Ministry of Fuel and Power.

References

Attygalle, D., Harrison, C. V., King, E. J., and Mohanty, C. P. (1955). In the press.

Bastenier, H. (1950). *Arch. belges. Méd. soc.*, **8**, 81.

Cavigneaux, A., Charles, A., Fuchs, S., and Tara, S. (1950). *Arch. Mal. prof.*, **11**, 34.

Griffin, O. G. (1954). Safety in Mines Research Establishment, Res. Rep. No. 101.

Kettle, E. H. (1934). *J. Path. Bact.*, **38**, 201.

King, E. J., Harrison, C. V., and Nagelschmidt, G. (1948). *Ibid.*, **60**, 435.

Lynch, K. M., and McIver, F. A. (1954). *Amer. J. Path.*, **30**, 1117.

Policard, A., and Collet, A. (1954). *Schweiz. Z. allg. Path. Bakt.*, **17**, 320.

Rüttner, J. R., Bovet, P., Weber, R., and Willy, W. (1952). *Naturwissenschaften*, **39**, 332.

Brit. J. industr. Med., 1956, **13**, 260

CARCINOMA OF THE LUNG IN WORKMEN IN THE BICHROMATES-PRODUCING INDUSTRY IN GREAT BRITAIN *

BY

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The chromates-producing industry provides the basic chromates, sodium and potassium dichromate or monochromate, from which metallic chromium and the chromium compounds used in industry are obtained. The process involves extraction of chromium from the ferrous ore known as chromite or chrome ironstone, $FeO.Cr_2O_3$ which contains 40 to 50% chromium and small amounts of alumina and silica. The ore is dried, crushed, mixed with limestone and the carbonate either of sodium or potassium and heated in a rotary furnace to convert the insoluble oxide to soluble monochromate. The monochromate is extracted from the furnace roast by repeated washing with water and treated with sulphuric acid to form dichromate, with sodium sulphate as a by-product.

Carcinoma of the lung in employees in the chromates-producing industry has been investigated and recognized as an occupational hazard in Germany (Pfeil, 1935; Alwens, Bauke, and Jonas, 1936; Teleky, 1936; Gross and Kölsch, 1943) and more recently in the United States of America (Machle and Gregorius, 1948; Baetjer, 1950a, b; Mancuso and Hueper, 1951; Gafafer, 1952). An investigation has been in progress in the industry in Great Britain since 1948 and the results are reported in this paper.

One of us has previously published the results of a clinical and radiographic investigation of men employed in the chromates-producing industry in Great Britain (Bidstrup, 1951). Seven hundred and twenty-four workmen were interviewed and radiographed and among these one was found to have carcinoma of the lung, from which he died during the survey. It was obviously not possible to decide whether this indicated a true increase of the incidence of carcinoma of the lung amongst these men, and an attempt has been made to follow the mortality experience of the remaining 723 persons from the time that the original survey finished on November 1, 1949, until August 31, 1955, a period of five years and 10 months.

The one case discovered in the course of the survey was found as a direct result of the investigations made at that time and is therefore disregarded in the statistical studies that follow, since it is obvious that the examinations made would tend to discover cases that might not otherwise have been correctly diagnosed. From the completion of the survey in 1949 until the further radiographic survey undertaken in 1955, the diagnosis of lung cancer as the cause of death in any individual case would have been made in a way not affected by a tendency to be looking for such a cause of death. In all cases the diagnosis was made either by the patient's usual medical attendant or in a hospital, but not by a works physician advised to keep an especial watch for such a condition. The doctors making the diagnosis would have no special knowledge of the previous survey and of the suspected risk so that there is no reason to believe that the results to be reported are affected by a diagnostic bias resulting from the investigation.

Method of Follow-up Study

The three factories at which the original survey was made are situated in different places in Great Britain. One is in a conurbation in England and Wales, one in a similarly constituted area in Scotland, and one in an urban area with a population between 50,000 and 100,000 in England and Wales. Because of geographical and other difficulties it was not possible to observe and record by personal interview the fate of each of the 723 workmen alive when the

*The term " chromates-producing industry " is used throughout this paper to refer to the manufacture of bichromates from chromite ore, and not to any of the industries in which chromium and its compounds are used.

survey ended in 1949. The method adopted was to supply the management at each works with a set of cards giving the name, address, and survey number of each man. When a man left the works for any reason his card was returned stating the date on which he left and the reason given for leaving. The fact that the reason for leaving is not known in only four cases is a measure of the effectiveness of the system, and of the cooperation of the management. These four cases have been included among those who have sought other employment since enquiries have failed to establish that they have died.

Results

Three hundred and thirty-three of the 723 men still alive when the 1949 survey ended are no longer employed in the chromates-producing industry. Table 1 shows the reasons given for leaving. Two

TABLE 1

REASONS GIVEN FOR LEAVING EMPLOYMENT IN CHROMATES-PRODUCING INDUSTRY

Factory	No. of Employees (1949)	Retired		Sought Other Employment	Died	Total
		Ill-health	Age			
I	179	1	4	79	9	93
II	500	4	45	130	48	227
III	44	1	2	8	2	13
Total	723	6	51	217	59	333

hundred and seventeen of these left at different times during the period 1949 to 1955 to seek other employment, and it has not been possible to discover what has happened to them. In the case of the 57 men who have retired because of age or ill-health, it has been possible to ascertain that they are still living and that none of them has symptoms suggestive of carcinoma of the lung.

Fifty-nine men are known to have died and the assigned cause of death was carcinoma of the lung in 12 cases (Table 2). The diagnosis was confirmed

TABLE 2

DEATHS BETWEEN NOVEMBER 1, 1949, AND AUGUST 31, 1955, IN 723 CHROMATES WORKERS EXAMINED IN 1949

Factory	Ascribed to Carcinoma of Lung	Ascribed to Neoplasms at Other Sites	Ascribed to Other Causes	Total
I	3	3	3	9
II	9*	6	33	48
III	†	—	2	2
Total	12	9	38	59

*One man from factory II who did not take part in the survey is known to have died from lung cancer.

†The diagnosis of lung cancer has been made in two other men who are still alive, one of whom took part in the survey.

by necropsy in four cases, and by histological examination of bronchoscopy specimens in three others. There seems to be no reason to doubt the diagnosis made on clinical and radiographic findings in the other five cases.

In nine cases death was ascribed to neoplasms at sites other than the lung and in the remaining 38 cases to other causes.

Three hundred and ninety of the original 723 men are still employed in the industry, and of these 367 have been radiographed again during 1955. One man aged 51 was found to have carcinoma of the lung, but was still alive at the end of August, 1955. Even had he been dead, the case could not have been used in the statistical analysis since the further radiography would have caused a bias in recognizing the condition.

Method and Results of Statistical Analysis

The method of analysis adopted has been based on the comparative composite cohort analysis technique described in detail by Case and Lea (1955) using analytical tables prepared for this purpose by Case and Pearson (1955). The tables selected were based on the years 1951, 1952, and 1953, the median years of the period of survey, and were compiled from statistics relating to the male population of England and Wales. An investigation had verified that the secular changes in all the age-specific death rates used were sufficiently near to being linear over the period of the survey, and the midpoint of 1951-53 sufficiently near to the midpoint of the period of the survey, to ensure that no appreciable error would be introduced by using these tables. Since one of the factories concerned was in Scotland, a special calculation was made from data published by the World Health Organization (1955) relating to age-specific death rates by sex for cancer of the respiratory system in England and Wales and in Scotland. This calculation verified that the use of tables based on England and Wales would not materially affect the calculations.

The method of analysis requires a statement of the number of years of life experienced by the 723 men in each of a series of age groups, grouped in five-year intervals, over the whole period of the survey. From this statement, the "expected" number of deaths from a particular cause can readily be calculated from the age-specific death rates from that cause given in the analytical tables. ("Expected" is used in this sense throughout this paper to mean the number of deaths from the particular cause being discussed that would have occurred had the mortality from that cause which affects the general male population of England and Wales acted with the same severity on the series of men being studied, due allowance being made for the age of the men and secular variations in the mortality rates.) Three categories of causes of death have been considered,

namely, deaths from carcinoma of the lung, deaths from neoplasms at other sites, and deaths from other causes. In all cases the entry on the death certificate which was used in our calculations was the cause of death to which the Registrars-General had assigned the death for the purpose of computing their returns.

The calculation of the statement of life experience in each age group is rendered more complicated than the similar calculation shown by Case and Lea (1955) because 217 men disappeared from observation by leaving their employment during the survey, but since we know both their age and the date at which each one left it has been possible to include the time that elapsed before they did leave in the statement. The results of the statistical analysis are shown in Table 3, and the figures are broken down to show the age distribution of the

TABLE 3
THE NUMBER AND AGE DISTRIBUTION OF DEATHS EXPECTED AND FOUND

	Age	<45	45—	55—	65+	All Ages
Carcinoma of Lung	Expected	1·3		2·0		3·3
	Found	7		5		12
	P for increase found					0·005
Neoplasms at other Sites	Expected	5·6		2·3		7·9
	Found	6		3		9
	P for difference					0·7
Other Causes	Expected	4·2	5·9	12·4	13·8	36·3
	Found	3	8	12	13	38
	P for difference					0·8

deaths found and expected in each of the three categories examined.

Discussion

The figures for deaths from neoplasms at other sites than the lung and for deaths from other causes can be dismissed very briefly since it is obvious that they do not show any statistically significant difference between the numbers found and expected for these causes of death nor does the age-distribution differ. We must therefore conclude that workers in the chromates-producing industry are not shown to suffer an excessive or to enjoy a diminished mortality from neoplasms other than carcinoma of the lung or from other causes of death.

When we come to consider the mortality from carcinoma of the lung, the figures show a statistically significant increase of deaths found over deaths expected from this cause ($P = 0{\cdot}005$ for the increase) and an excessive mortality from carcinoma of the lung must therefore be admitted. The figures for the distribution of the deaths also show a tendency for deaths to be occurring disproportionately early, and although the scanty amount of data available here does not allow us to claim that the figures are statistically significant, the trend is discussed because such an alteration in mortality pattern would be expected if an environmental cause of death with a fairly well defined latent period of around 15 to 25 years were to be superimposed on the pre-existing mortality pattern of a community like that described here (*cf.*, Case, Hosker, McDonald, and Pearson, 1954).

The ratio between the mortality found from carcinoma of the lung in this sample of workers in the chromates-producing industry and that expected is 360%, and it remains to consider whether any factors not connected with occupation might be operating amongst these men which could lead to a difference of this magnitude. The main differentials of this sort that have been established as affecting the incidence of carcinoma of the lung in large communities are sex, which is irrelevant to these studies, place of residence, social class, and smoking habits.

Place of Residence.—The population in the three factories is about evenly distributed between dwellers in a conurbation and dwellers in an urban area with a population in the range 50,000 to 100,000 persons. The fact that part of the conurbation population is resident in Scotland has already been shown to be immaterial. The Registrar-General (1954) gives the age-specific death rates for carcinoma of the lung in 1951 for the various population density aggregates for England and Wales, and reference to these figures will show that whilst the rates for the conurbations are about 10% above the mean rate for males in England and Wales, the rates for the urban areas with populations in the range of 50,000 to 100,000 are almost that amount below the mean rate. The contribution to the findings due to place of residence must therefore be considered as trivial.

Social Class.—The chromates workers taking part in this investigation are mainly in social classes IV and V. Logan (1954) has studied the social class differences in mortality from carcinoma of the lung revealed by the 1951 census, and shows that, whilst there is now a suggestion of a social class gradient which was not apparent in 1921 or 1931, the standardized mortality ratios for social classes III, IV, and V are respectively 108%, 89%, and 116% of the rate for the general population of males aged 20-64. We must therefore conclude that the differences due to social class could not contribute materially to the differences that we have found.

Smoking Habits.—It might be suggested that the workmen in the chromates-producing industry include many heavy smokers, and that the deaths from lung cancer occurred entirely amongst these men. The general population includes a certain proportion of heavy smokers, and it would be necessary to postulate that the proportion of heavy smokers in the group under investigation was so much greater than in the general population that an increase of 360% of the mean rate would result. Stocks and Campbell (1955) give figures that probably reflect the smoking habits of the general population with a fair degree of accuracy, and their sample suggests that for urban areas, which would include conurbations, the percentage distribution of smoking habits for men aged 45-64 is non-smokers 3·9%, pipe-smokers 7·1%, cigarette-smokers—light 17·6%, moderate 61·5%, and heavy 10·5%. Doll and Bradford Hill (1954) show that the incidence in their heaviest group of smokers defined as those who smoke more than 25 cigarettes a day, and roughly comparable with the definition of "heavy smoking" adopted by Stocks and Campbell, was just less than double (200%) that of the mean rate for the general population, whilst the rate in the group corresponding to Stocks and Campbell's moderate smokers was about the same as the mean rate for the general population. Thus even if the smoking habits of the chromates workers were so changed from those of the general population that all of them fell into the category of heavy smokers, the increase of carcinoma of the lung that would then be expected would not satisfactorily account for the increase which we have observed. In fact, we have no reason to believe that their smoking habits are different from those of the general population, and an explanation based on a hypothesis of altered smoking habits would need to be supported by satisfactory evidence of such alteration before it could be seriously considered.

It would therefore seem that, in our present state of knowledge, the increased mortality from carcinoma of the lung which we have found amongst these workmen in the chromates-producing industry must be attributed to some factor associated with their occupational environment, and could not be explained by variations of mortality due to place of residence, social class, or smoking habits. We have expressed the opinion earlier that a diagnostic bias can also be excluded as a factor.

The survey was not designed to determine, and was inherently incapable of determining, the nature of the carcinogenic occupational factor.

The Latent Period.—Since only 12 deaths from carcinoma of the lung are considered in this series the number is too few to allow of an accurate calculation of the mean latent period after first exposure to risk. From the grouped data given in Table 4 the mean latent period is calculated to be 21 years with a standard deviation of 10 years and a standard error of the mean of three years. This

TABLE 4

ANALYSIS OF DEATHS ASCRIBED TO CARCINOMA OF LUNG

Year of Death	Latent Period in Years*				Total	Age at Death	
	<10	10–	20–	30–39			
1950			1		1	30	1
1951		1	1		2	30–	0
1952		1			1	35–	1
1953	1				1	40–	0
1954	1	1	1	1	4	45–	1
1955			2	1	3	50–	4
						55–	1
						60–	1
						65–	3
Total ..	2	3	5	2	12	Total	12

*Mean latent period 21 ± 10 years. $\sigma m = 3$ years.

suggests that the latent periods which might occur in cases of carcinoma of the lung amongst workers in the chromates-producing industry will not differ greatly from those found for other types of cancer of occupational origin such as cancer of the bladder in the dyestuff—intermediates industry, for which the latent period is 18 years with a standard deviation of seven years (Case and others, 1954).

Where there is a long latent period of this kind calculations purporting to show the ratio between the risk in a given industry and the risk in the general population are relatively meaningless unless a sufficient number of cases have been studied in a sufficiently large population at risk to allow the calculations to be made of the final incidence of the particular cause of death in a cohort followed to extinction, and the figure so obtained to be compared with a similar final incidence figure for the general population (*cf.*, Case and others, 1954). Thus the statement that an increase of 360% of the mean rate has so far been found is not a final statement that the risk in the chromates-producing industry is only 360% of the mean, for by the time all the men at risk have lived their life span it will probably be found that the factor is very much higher.

There is therefore no point in trying to relate the quantitative results of this survey to the statement of Machle and Gregorius (1948) that the crude death rate amongst their workers in the chromates-

producing industry in the United States of America was 25 times the normal. The results do, however, confirm from British data the conclusions of these authors and of other American authors (Baetjer, 1950a, b; Mancuso and Hueper, 1951; Gafafer, 1952) and also the conclusions of the German authors (Pfeil, 1935; Alwens and others, 1936; Teleky, 1936; Gross and Kölsch, 1943) that carcinoma of the lung is an occupational hazard of the chromates-producing industry.

Summary

A follow-up over about six years of the mortality experience of workers in the chromates-producing industry at three factories in Great Britain shows a statistically significant increase in the mortality from carcinoma of the lung. Twelve deaths were recorded in the series used for statistical analysis and only 3·3 expected. In addition to these 12 patients, three more, one of whom is dead and two still alive, were reported from the same factories.

This increased mortality is in accord with the findings of various authors (previously quoted) who have studied hazards to health in the chromates-producing industry in Germany and in the United States of America.

The possibility that the increase found by us could be due to a non-occupational cause such as diagnostic bias, place of residence, social class, or smoking habits has been examined, discussed, and discarded, and we therefore conclude that carcinoma of the lung must be considered as an occupational hazard in the chromates-producing industry in Great Britain. The data that we have examined do not allow us to form any opinion about the nature of the carcinogenic occupational factor.

The mortality experience of the chromates workers taking part in this investigation from neoplasms at other sites and from deaths from other causes does not seem to be altered from the mortality expected in a comparable section of the general population of England and Wales.

We acknowledge the cooperation of the companies concerned throughout these investigations and particularly in making available to us the information about the employees who took part in the 1949 survey on which the follow-up study and conclusions reported here are based. It would not have been possible to make the investigation without the assistance which the firms have given at every stage of our enquiries. We acknowledge also the cooperation of many doctors who have sent us copies of case-records and necropsy reports.

We are grateful to Dr. Donald Hunter, Director of the Department for Research in Industrial Medicine, Medical Research Council, London Hospital, for advice and criticism.

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References

Alwens, W., Bauke, E. E., and Jonas, W. (1936). *Arch. Gewerbepath., Gewerbehyg.*, **7**, 69.
Baetjer, A. M. (1950a). *Arch. industr. Hyg.*, **2**, 487.
——, (1950b). *Ibid.*, **2**, 505.
Bidstrup, P. L. (1951). *British Journal of Industrial Medicine*, **8**, 302.
Case, R. A. M., and Lea, A. J. (1955). *Brit. J. prev. soc. Med.*, **9**, 62.
——, and Pearson, J. T. (1955). Methods and Tables for Comparative Composite Cohort Analysis. (1) Tables. Neoplastic Diseases. London. Institute of Cancer Research. Royal Cancer Hospital. (Unpublished Institute Record.)
——, Hosker, M. E., McDonald, D. B., and Pearson, J. T. (1954). *British Journal of Industrial Medicine*, **11**, 75.
Doll, R., and Hill, A. B. (1954). *Brit. med. J.*, **1**, 1451.
Gafafer, W. M. (1952). Publication 192. Federal Security Agency, Washington. U.S. Public Health Service.
Gross, E., and Kölsch, F. (1943). *Arch. Gewerbepath. Gewerbehyg.* **12**, 164.
Logan, W. P. D. (1954). *Brit. J. prev. soc. Med.*, **8**, 128.
Machle, W., and Gregorious, F. (1948). *U.S. Publ. Hlth Rep.*, **63**, 1114.
Mancuso, T. F., and Hueper, W. C. (1951). *Industr. Med. Surg.*, **20**, 358.
Pfeil, E. (1935). *Dtsch. med. Wschr.*, **61**, 1197.
Registrar-General (1954). Statistical Review of England and Wales for 1951. Text volume p. 198. H.M.S.O., London.
Stocks, P., and Campbell, J. M. (1955). *Brit. Med. J.*, **2**, 923.
Teleky, L. (1936). *Dtsch. med. Wschr.*, **62**, 1353.
World Health Organisation (1955). *Epidem. vital. Statist. Rep.*, **8**, 265.

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CANCER IN COKING PLANT WORKERS

BY

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A review of death certificates, received in connexion with a funeral benefit scheme, suggested to the officials of the National Union of Mineworkers that there seemed to be an unduly high proportion of deaths due to cancer among workers in coking plants. At the request of the National Joint Consultative Council, a special study was made of the mortality experience of the industry. Its methods and results are reported below.

Apart from an unpublished report by Sir Thomas Oliver in 1930, little has been written about the health of workers in the coking plants of this country; and Oliver's study is impressionistic rather than factual in its approach. Indeed it is usual for coke-workers to be taken together with gas workers in the Registrar-General's account of occupational mortality. The basic processes in the production of metallurgical coke and of gas for industrial or domestic use are, of course, similar, and strong suggestions of an increased liability of gas workers to cancer of the skin and bladder (Henry, Kennaway, and Kennaway, 1931) and of the lung (Kennaway and Kennaway, 1947; Doll, 1952) are relevant to our problem. Thus we note that in Table I skilled gas workers had, at all ages over 35, higher death rates from cancer than males of the same social class.

TABLE I

CANCER DEATH RATES IN SKILLED GAS WORKERS AND MALES OF SAME SOCIAL CLASS* (REGISTRAR-GENERAL'S DECENNIAL SUPPLEMENT ON OCCUPATIONAL MORTALITY 1930-32)

Group	Age					
	35–	45–	55–	65–	70–	75–
All males in social class IV	0·5	1·6	4·7	8·9	11·8	15·1
Skilled gas workers	0·6	2·6	7·0	19·3	18·6	20·3

*Rates per 1,000 per annum.

These results apply to makers of gas and coke in general, but there are differences between coking plants and gas works—in the type of coal and the methods of its treatment—which may affect the production of carcinogenic agents and the resultant cancer mortality. A special enquiry in coking plants was clearly required.

Conduct of Survey

Through the cooperation of the Carbonization Department of the National Coal Board and the Cokemen's Area of the National Union of Mineworkers, a complete record was obtained of the occupational histories of all men dying while still on the books of N.C.B. coking plants during the period 1949-54 inclusive. The cause of death in each case was ascertained either by reference to claims made on the Union's funeral fund, which had to be supported by a copy of the death certificate, or by a special search at the General Register Office. During the period of review, the average number of men employed in N.C.B. coking plants was about 8,000. A special census taken in 1952 gave a breakdown of this total by present job and age. At the same time a quasi-random sample was selected by taking every tenth man on the alphabetical lists of employees on the weekly payroll of each coking plant. For this 10% sample of the men employed a more detailed history was obtained of the nature and duration of different jobs done while working in the plants.

Information was also available from the funeral fund on the causes of deaths among individuals dying after their retirement from the plants, but no record had been kept of the number and age distribution of all such former employees, living or dead. For those dying within the period 1949-54, however, the past occupational history was obtained from the coking plants.

Method of Analysis

To the total number of man-years of exposure over the period 1949-54, divided according to the age and job distribution given in the special census in 1952, have been applied the cause and age-specific

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TABLE 2

COMPARISON OF OBSERVED DEATHS ACCORDING TO LAST JOB WITH DEATHS EXPECTED AT OTHER INDUSTRIAL RATES

Cause of Death	Oven Workers		By-product Workers		Maintenance						Total	
					Labourers		Workers		Foremen			
	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected
Cancer of respiratory tract	4	5	3	3	2	6	10	7	2	1	21	23
All cancer	24	16	9	9	10	21	22	24	6	3	71	73
Other causes	50	49	29	26	57	60	95	72	14	9	245	216
Total, excluding cancer of respiratory tract..	74	65	38	35	67	81	117	96	20	12	316	289

death rates prevailing in the period 1950-54 in a large industrial organization. These rates were similar to those found in the General Post Office during a corresponding period but were more useful in that they extended beyond the usual retiring age of 60 for civil servants. Sick leave arrangements and the period of retention on the books during prolonged illness were similar in the two industrial groups. (National death rates make a less suitable standard of comparison since they derive from all male deaths including those of chronically incapacitated men.) The application of these standard age-specific rates to the corresponding age groups of men in different jobs gave a total of expected deaths which could be compared with those actually reported in the coking plants. Since no population data were available, only proportional death rates could be calculated for ex-employees.

The many types of worker in a coking plant seem to fall naturally into four main groups. The first of these consists of men who operate the coking ovens, driving the ram, filling the oven, clearing the hydraulic main, etc. The second group consists of men working on the recovery of by-products such as tar, ammonia, and benzole, while the last two include labourers—whose duties and contacts vary greatly—and another broad group of maintenance men and craftsmen who from time to time are in contact with the processes. Foremen, who have a roving supervisory commission, may also be separated out. These are the occupational groups used in the analysis.

Summary of Results

Cancer in Present Employees.—Table 2 shows the numbers of deaths, both from cancer and from all other causes, in each occupational group observed and expected at standard rates. In total there is no excess in the number of cancer deaths, and the slight excess in deaths from other causes suggests that there has been no serious under-reporting of deaths in coking plant staff. This excess of deaths from other causes comes entirely in the maintenance group which may have contained a number of men doing lighter tasks because of indifferent health. Of particular importance is the complete lack of any excess in cancer of the respiratory tract among men working on the ovens where exposure to fumes might be expected to be greatest.

" Present job " may not, however, be the best indicator of past occupational exposure in the coking industry. From the sample survey of occupational histories the frequency of having worked either on the ovens or in the by-product section of the plant was computed for men in each age and each " present job " group. The application of the same standard death rates as used before gave the expected numbers of deaths, which are compared in Table 3 with the numbers reported. There is close agreement between expectation and observation in those who have at any time worked in the by-product sections. This suggests that by-product process work is not associated with any excessive cancer risk. Among the oven workers, past and present, there is some apparent excess in the number

TABLE 3

COMPARISON OF OBSERVED AND EXPECTED DEATHS ACCORDING TO OCCUPATIONAL EXPOSURE

Cause of Death	Men Employed at Any Time as Oven Workers		Men Never Employed as Oven Workers		Men Employed at Any Time as By-product Workers		Men Never Employed as By-product Workers	
	Observed	Expected	Observed	Expected	Observed	Expected	Observed	Expected
Respiratory cancer	14	10	7	13	4	6	17	17
All cancers	40	32	31	41	16	18	55	55
Other causes	71	95	174	121	46	53	199	163
Total, excluding cancer of respiratory tract.. ..	111	127	205	162	62	71	254	218

of deaths due to cancer and four out of the seven extra cases died from cancer of the respiratory system. This excess is small and might well have occurred purely by chance. It should be pointed out, however, that past histories for the dead men may not be as reliable as the occupational records available for those still employed in the industry, and that the frequency of oven exposure among the former may be understated. Table 3 certainly does show an excessive number of deaths from other causes among the "never employed" groups but there is no corresponding excess in the cancer deaths which might be masking a real occupational hazard.

Cancer in Former Employees.—Since we do not know the age distribution of men who have retired from work in the coking plants, we cannot make the same type of comparison between the number of deaths from cancer and other causes observed among them with the number to be expected at standard rates. We can only assume that if the death rate from other causes is the same in groups of men who had done different jobs in the coking plants any serious excess in cancer death risk will be reflected in a high proportion of the total number of deaths in a particular occupational group being due to cancer. The first section of Table 4 shows the number of deaths among former coking plant employees divided according to the job done before retirement; the second section gives the proportional death rates for all types of cancer (as a percentage of all deaths) and for lung cancer (as a percentage of all cancers) in each of those occupational groups. As Table 4 shows, these proportional death rates do not differ greatly between the groups. In view of the small numbers on which the rates are based, such differences as there are might well be due to chance; and there is certainly no suggestion that either of the proportional cancer death rates is unduly high among former oven workers.

These deaths have been arranged according to the last job in the coking plant, but because of failing health in their later years some men may have changed their job in the plant before final retirement. The deaths and proportional death rates, calculated as above, are given in Table 5 for groups of men who have worked for some time on either the ovens of the by-product sections and for the remainder of the plant staff in each case.

Again there is no important difference in the proportional rates in the four contrasting groups. This constancy in proportional rates suggests that they are not being unduly affected by the differences in the death rates from other causes, which is the

TABLE 4

DEATHS AND PROPORTIONAL DEATH RATES BY FORMER OCCUPATION IN RETIRED EMPLOYEES

Cause of Death	Oven Workers	By-product Workers	Labourers	Maintenance Workers	Foremen	Total
Deaths and Previous Occupation						
Respiratory cancer	3	4	4	3	1	15
All cancer	12	12	11	12	4	51
Other causes	43	25	42	30	8	148
Total, excluding respiratory cancer . .	55	37	53	42	12	199
Proportional Death Rates and Previous Occupation						
Respiratory cancer / All cancer	25	33	36	25	25	30
All cancer / Total deaths	22	32	21	23	33	26

TABLE 5

DEATHS AND OCCUPATIONAL HISTORY

Cause of Death	Men Employed at Any Time as Oven Workers	Men Never Employed as Oven Workers	Men Employed at Any Time as By-product Workers	Men Never Employed as By-product Workers
Respiratory cancer	5	10	4	11
All cancer	23	28	15	35
Other causes	64	84	30	118
Total, excluding respiratory cancer . .	87	112	45	153
Proportional Death Rates and Occupational History				
Respiratory cancer / All cancer	22	36	27	31
All cancer / Total deaths	26	25	33	23

usual source of their unreliability. Indeed, the indications given by these rates are remarkably consistent with the age-standardized comparisons already made for the employed men in suggesting that there is no grossly excessive cancer death risk in any particular occupational group.

The increase in respiratory cancer in men who have worked on the ovens can be further studied by taking duration of exposure into account. The number of years of employment in the coking industry and the number of years spent working on the ovens for 20 of the men dying from respiratory cancer while still on the books, for whom detailed histories were available, are compared in Table 6 with similar durations for men of similar age still alive and selected at random from those included in the occupational sample survey. There is no suggestion apparent in these data that the occupational history of the men dying from respiratory cancer differs appreciably from that of a random sample of coking plant employees of the same age.

TABLE 6

DURATION OF EMPLOYMENT IN RESPIRATORY CANCER DEATHS AND SAMPLE EMPLOYEES

	Respiratory Cancer Deaths	Sample
Oven work	16·3	16·7
Total in coking plant	23·0	25·3

Cancer of the Bladder.—In view of the suggestions that gas workers have an excessive mortality rate from cancer of the bladder, the national age-standardized cancer of the bladder death rates for the years 1949-54 inclusive (Case, 1953) have been applied to the N.C.B. coking plant population. The deaths upon which the rates tabulated by Case are based will include deaths occurring among men removed from the books of firms after prolonged absence from work. Despite this, there is a close agreement between the numbers expected at these national standard rates (five) and the numbers actually reported (four) in the N.C.B. coking plants during the period of the survey.

Discussion

The results obtained seem to imply that as far as recent experience in the coking industry goes, there is no great excess in cancer mortality in general nor in respiratory cancer in particular, even among the men who have worked on the ovens. This finding differs from the results of earlier work on the mortality of workers in the gas industry (Kennaway and Kennaway, 1947; Doll, 1952) which suggested a twofold increase in respiratory cancer among men in that industry.

The agreement between observation and expectation for other causes of death suggests that the methods of collecting population data, the reporting of deaths, and the application of standardized rates were reasonably efficient. With the numbers involved in this study we could anticipate being able to detect as large a difference as a twofold increase in respiratory cancer. That the excess is apparently now less than this may be due to several factors. Quite apart from differences in plant siting or operation, present conditions in the coking industry may be quite different from those prevailing in the gas industry a generation ago; and previous mortality studies were based on the experience of the earlier generation. Of greater importance, however, is the great change in the prevalence of cancer of the lung in the general population: the crude death rate in males increased fivefold in 20 years.

If this increase is due to a universal habit like cigarette smoking the effect of occupational exposure to industrial air pollutants may be submerged. For these reasons, we may conclude that, relative to current risk in the population at large, the mortality in the coking industry from cancer in general and cancer of the lung in particular, is not as excessive as had been feared, and may in fact be negligible. To give a more precise answer, large-scale follow-up studies, such as the one now in progress in the gas industry, would be required.

Summary and Conclusions

The number of deaths from cancer and other causes in the coking plants of the National Coal Board during 1949-54 inclusive have been compared with numbers expected on the basis of the mortality experience of another large industrial organization. No general excess of deaths from cancer was found either in the coking plant population as a whole or in particular occupational groups. An excess in the number of cancer of the lung deaths among men who had worked on the ovens was not paralleled by any increase in proportionate cancer of the lung death rates among retired oven workers nor by any difference in occupational exposure between 20 men dying from cancer of the lung and other employees still at work and of the same age.

The reasons for this apparent divergence between past experience in similar industries and present experience in N.C.B. coking plants are discussed.

We are indebted to the National Coal Board for providing, through the Epidemiology Panel of the N.C.B. Medical Service, facilities and expenses. Our thanks are also due to officials of the General Register Office, the N.C.B. Carbonisation Department, and the Cokemen's Area of the National Union of Mineworkers.

REFERENCES

Case, R. A. M. (1953). *British Journal of Industrial Medicine*, **10**, 114.
Doll, R. (1952). *Ibid.*, **9**, 180.
Henry, S. A., Kennaway, N. M., and Kennaway, E. L. (1931). *J. Hyg. (Camb.)*, **31**, 125.
Kennaway, E. L., and Kennaway, N. M. (1947). *Brit. J. Cancer*, **1**, 260.

THE JULY (1956) ISSUE

The July (1956) issue contains the following papers:—

Sixty Years of Industrial Medicine in Great Britain. By Andrew Meiklejohn.

Occupational Medicine as a Vocation. By James A. Smiley.

The Relationship between Ventilatory Capacity and Simple Pneumoconiosis in Coalworkers. By R. G. Carpenter, A. L. Cochrane, J. C. Gilson, and I. T. T. Higgins.

Factors Influencing the Radiological Progression Rate of Progressive Massive Fibrosis. By A. L. Cochrane and R. G. Carpenter, with the assistance of W. G. Clarke, G. Jonathan, and F. Moore.

Pneumoconiosis in Central Indian Coal-mines. By K. B. Roy.

A Study of Dust Toxicity Using a Quantitative Tissue Culture Technique. By J. Marks, M. Ann Mason, and G. Nagelschmidt.

A Quantitative Technique for Studying the Effect of Dust on Phagocytic Cells *in vitro*. By J. Marks and M. Ann Mason.

The Use of a Size Selector for Dust Sampling with the Thermal Precipitator. By J. T. Burdekin and J. G. Dawes.

The Use of the Pulheems System of Medical Classification in Civilian Practice. By M. D. Warren.

Determination of Atmospheric Benzine Concentration by Displacement following Adsorption on Silica Gel. By Per Övrum.

Two Cases of Poisoning with Di-isopropylfluorophosphonate (D.F.P.). By W. K. S. Moore.

Arsine Poisoning. By D. Blair Macaulay and D. Austen Stanley.

Association of Industrial Medical Officers: Programme of 21st Anniversary Meeting.

Miscellanea:

The Prescription of Industrial Disease. By Ronald E. Lane.

Book Reviews

A number of copies are still available and may be obtained from the Publishing Manager, British Medical Association, Tavistock Square, W.C.1, price 12s. 6d.

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THE CYTOLOGICAL DIAGNOSIS OF BLADDER TUMOURS AMONGST DYESTUFF WORKERS

BY

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Tumours of the urinary bladder occurring amongst the general population usually disclose their presence by the onset of symptoms such as haematuria, dysuria, frequency, or pain. In some cases haematuria may develop from a small benign papilloma which offers a good chance of successful treatment, whilst in others the tumour may have reached large proportions and even metastasized before its discovery.

In 1920 Oppenheimer in Germany recommended regular microscopical examination of the urine for the presence of red blood cells as a means for the earlier detection of occupational bladder tumours. For similar reasons in 1934, Cresdee, Guest, and Wignall (unpublished) instituted such regular examinations in two British dyestuffs factories and shortly afterwards Hope and Scott (unpublished) applied them in a third factory. They hoped that red blood cells or other abnormal constituents in the urine might give an indication for cystoscopy before the onset of symptoms due to a tumour so that earlier diagnosis might afford a chance of more effective treatment. During the next 15 years Cresdee, Goldblatt, Scott, and Williams (unpublished) in Great Britain extended these examinations of wet unstained smears of urinary sediments to include more men at more frequent intervals. Many cases diagnosed by this means were included amongst those described by Goldblatt (1949) and by Scott (1952) and all of them were included in the figures used by Case, Hosker, McDonald, and Pearson (1954), and Case and Pearson (1954) in their survey of the incidence of the disease in Great Britain. They confirmed statistically that there was a significantly higher incidence of bladder tumours amongst men exposed to α- and β-naphthylamine and benzidine than in the general population and revealed an occupational hazard of bladder tumours amongst men engaged in the manufacture of magenta and auramine.

Similar examinations of wet smears of urinary sediment have been used as an indication for cystoscopy in Germany for a number of years (Gross, 1940). In Switzerland, however, the urine was examined for occult blood in 1932 but by 1937, after consultation with American colleagues, routine cystoscopy was chosen as the most efficient method of achieving early diagnosis (Müller, 1951). Routine annual cystoscopy of exposed workers was first instituted in the United States of America in 1931 and has continued until recently with concurrent examinations of wet smears (Gehrmann, 1934; Gehrmann, Foulger, and Fleming, 1949). They even advocate the cystoscopy of all men before starting work. Similarly this procedure was adopted early in Italy and still continues to be applied (di Maio, 1937 and 1949). Many tumours have been diagnosed in this way, but there is no indication of what proportion of unaffected men have continued to undergo cystoscopy annually for up to 20 years. It is claimed by the above authors that regular annual cystoscopy can be achieved. In France Billiard-Duchesne (1949) published the results of his cystoscopies, but Aboulker, Gaultier, Benguigui, and Smagghe (1949) record the successful use of the wet smear technique which suggests that routine cystoscopy was not acceptable to them.

In Great Britain it is admitted that, although a substantial proportion of healthy men who have been at high risk might undergo cystoscopy on first demand, with repetition the numbers would quickly dwindle to levels which would invalidate any of its alleged advantages. Cystoscopy may be accompanied by some discomfort and is an operation which must be performed with great care if all sequelae are to be avoided. In Great Britain it has been the practice to restrict it to the necessary minimum. Furthermore, in practice, routine cystoscopy cannot be extended effectively to those persons with a relatively small exposure to carcinogens but

who still have a remote chance of developing a bladder tumour. Some tumours may grow to inoperable proportions in a year, so that an annual cystoscopic examination does not afford complete cover, even if there were no defaulters and no complications.

For the reasons given above, routine cystoscopy was considered to be quite unsuitable for introduction into British factories. Since their inception in 1934, the examinations of wet unstained smears of urinary deposits have resulted in many presymptomatic diagnoses, but despite these successes, some cases were only discovered when inoperable.

The work of Papanicolaou and Marshall (1945) and of Papanicolaou (1947) suggested that a study of cells exfoliated from the bladder epithelium into the urine might offer another method of screening the population at risk. Accordingly in 1951 the Papanicolaou smear technique of urine examination was introduced into the three factories alongside the original wet, unstained smear technique. A preliminary report on the results of the first year of its application has been given by Crabbe (1952). These results were sufficiently encouraging to warrant the continuation and extension of the Papanicolaou technique during subsequent years and the subject of this paper is the evaluation of each of the two techniques against the symptoms and cystoscopic findings.

Methods

Collection of Samples.—At first, urine samples were collected only from men working on suspect processes. When, however, some successes had been achieved, the wet smear examinations were extended to cover men who had left the hazardous processes and were employed on other work in the factory.

More recently, in two of the factories, the working histories of all persons employed have been examined and the employment cards of all persons who have at any time had the possibility of contact with known or suspected carcinogens are marked for the collection of urine samples. No difficulty has been experienced in obtaining samples and their regular collection is now regarded as one of the routines of factory life. A large proportion of men exposed to carcinogens in the past are now employed in a multitude of unrelated jobs elsewhere in the factories, and must be specially sought out to give their regular samples. The bottles are delivered to the men in the afternoon and collected full next morning.

In the third factory it has been possible to examine the urine of all the men. For geographical reasons it is convenient for them to attend at the surgery to void their samples. It is preferable to collect the urine in two jars and discard the first containing contamination from the urethra and prepuce, but this was only possible in the one factory where the men attend at the surgery, or when a special sample is demanded.

Wet Smear Technique.—About 10 to 15 ml. of fresh urine is centrifuged at approximately 2,000 r.p.m. for 15 minutes. A drop of the sediment is placed on a microscope slide. A cover slip can be applied, but this is not necessary for low- or medium-power examination and much time can be saved by dispensing with it.

The presence of red blood cells, leucocytes, and epithelial cells is noted, and a rough count of red cells is made. An experienced technician very quickly develops the ability to assess the number of cells present at a glance.

The decision to advise cystoscopy on wet smear examination alone always rests on the results of repeated examinations unless the urine contains sufficient blood to be visible to the naked eye, when cystoscopy becomes imperative. One of us (T. S. S.) examined the urine of 2,000 consecutive male applicants for employment, none of whom had previously been exposed to chemicals, and 124 (6·2%) were rejected because of considerable numbers of red blood cells in the urine although there was no other factor which on physical examination would have been cause for rejection. Apart from this presence of red cells in the urine of a proportion of apparently healthy men, such cells may appear in the urine from other causes such as calculi, infection, or renal or prostatic disease; the problem is further intensified by the fact that certain aromatic amines, such as ortho-toluidine and 5-chlor-2-toluidine, can cause acute chemical cystitis with haematuria so that if a man with microscopic haematuria has a history of recent contact with such amines further urine examinations after his removal from exposure are necessary. Thus microscopic haematuria in a single sample cannot be taken as an absolute indication for cystoscopy.

The wet smear technique has diagnosed many tumours but is not specific. Where no tumour was detected other conditions of the urinary tract were occasionally found. Sometimes, however, a man with no detectable cause for the microscopic haematuria would undergo a negative cystoscopy on two or three occasions and then refuse at the very moment when cystoscopy was vital.

Although the presence of an abnormal number of red blood cells has been the usual criterion for cystoscopy, as pointed out by Nassauer (1920) the presence of pus cells in the urine of men previously exposed to carcinogens is also an indication for further investigation.

Each man's case has to be considered individually, taking into account the intensity and duration of exposure, the nature of the carcinogen and the time that has elapsed since first exposure, together with the severity and duration of the urinary abnormalities. For instance, inconclusive wet smears combined with a history of long and severe exposure would lead the medical officer to advise cystoscopy more readily than if the exposure had been moderate or negligible.

Papanicolaou Smear Technique.—About 40 ml. of urine is centrifuged at approximately 2,000 r.p.m. for 15 minutes and a portion of the sediment is smeared on to an albuminized slide. Without letting the smear dry, it is immediately placed in a fixative solution consisting of equal parts of 95% ethanol and ether for a minimum time of 10 minutes. It is then stained with haematoxylin,

counterstained, and mounted. The preparations are permanent and can be kept indefinitely. A detailed description of this technique has been given by Papanicolaou and Marshall (1945).

Although it is preferable to use freshly voided urine when possible, this is not absolutely necessary. It has been stated by Sawaya, Sandin, and de Almeida (1954) that specimens of urine must be processed within one hour of micturition as the cells may be so altered as to render interpretation impossible. We have found that even in unfixed urine, cellular degeneration does not proceed so rapidly and the addition of absolute alcohol serves to fix and preserve the cells for as long as 96 hours at room temperature. It was, therefore, possible to collect the specimens at convenient points in two of the factories and to deliver them to the laboratories for processing later.

Sediments from the majority of both fresh and fixed normal urines contain so few cells that they appear to be almost acellular, and in order to reduce the time spent on the examination of the slides various methods have been devised to concentrate more cells into each smear. Chute and Williams (1948) and Ruth Graham (1950) advocate making smears from the pooled deposit of the whole urine samples. Deden (1954), on the other hand, allows 200-400 ml. of urine to stand for six hours in a separating funnel and then centrifuges the sediment, while Rofe (1955) removes the non-cellular elements by differential centrifugation and the mucus by solution in water after fixation of the cells. Though these methods are too prolonged for a busy laboratory where many urines per day are being processed, a modified form of differential centrifugation is being used successfully in one of our laboratories.

The interpretation of the smears is difficult and requires a thorough knowledge not only of the criteria of malignancy as laid down by Papanicolaou in his atlas (1954) but also of the numerous variations from the normal due to non-neoplastic conditions. While anyone can be trained in a matter of weeks to identify and record blood and epithelial cells in wet smears, it takes many months of instruction and practice before a technician can make a reliable assessment of the cytological characteristics of exfoliated cells. The results are interpreted as follows:—

Class I ..... Normal Class II ..... Atypical	Negative
Class III	Suspicious
Class IV .....Probably malignant Class V .....Definitely malignant	Positive

A positive result is considered an indication for cystoscopy. Suspicious smears are regarded as positive if exposure has been heavy or if blood is also present, but in other cases repeated samples are examined until a decision can be reached. The cases presented below will serve to illustrate the application of the Papanicolaou technique:—

Case 1.—This man was aged 51 when the tumour was found. He had been exposed to the manufacture of benzidine for seven years from 1933.

Routine wet smears of urine had been done from 1937 but had never suggested the presence of a tumour. Papanicolaou tests since 1951 were negative until May, 1955, when a suspicious result (Class III) was noted. Early in June the smear was Class II but on June 30 it became positive (Class IV). Cystoscopy on July 4 revealed a papilloma and this was confirmed as a benign tumour on biopsy.

Case 2.—This workman was aged 49 when the tumour was found. He had been exposed to benzidine for 20 years, from 1931.

His urine had been tested for R.B.C.s from 1943 onwards and showed no significant quantity of blood cells. Papanicolaou smears made on two separate occasions in December, 1953, were definitely positive. Because of this he was cystoscoped on January 25, 1954, and a small area of malignant tumour was revealed which was confirmed as transitional cell carcinoma by biopsy.

Results

During the five years 1951 to 1956 the urines of approximately 1,800 men were screened by the Papanicolaou smear technique and also, except for three cases, by the wet smear technique.

Of these 1,800 men, 91 were cystoscoped as a result of the two tests or on account of developing symptoms and 62 new cases of bladder tumour were discovered. The results are shown in Table I. (The examination of the urines of those men with a previous history of treated bladder tumour who have been under regular cystoscopic review is considered separately.)

Fifty-one men with positive Papanicolaou smears showed bladder tumours on first cystoscopy (true positives). (*a*) Twenty-six had symptoms and/or

TABLE I

SMEAR RESULTS AND FINDINGS IN 91 MEN CYSTOSCOPED

Cystoscopic Findings	Smear Results and Findings in 91 Men Cystoscoped						
	True Positives	Probably True Positives	False Negatives	Total	False Positives	True Negatives	Total
Symptoms and/or R.B.C.s	26	4	6	36	4	18	22
No symptoms	26*	1	–	27*	6	–	6
Total	52	5	6	63*	10	18	28

* One case of carcinoma of the prostate.

showed R.B.C.s on microscopy sufficient in themselves to be an indication for cystoscopy. (*b*) Twenty-five had not at any time had R.B.C.s or any other indication that a tumour was present. One man had positive Papanicolaou smears but no bladder tumour on cystoscopy, although a carcinoma of the prostate was discovered on clinical examination.

Five men with positive Papanicolaou smears, although showing no tumours on first cystoscopy, developed bladder tumours from five months to four years later (probably true positives). (*a*) Four had symptoms or R.B.C.s sufficient to warrant cystoscopy in any case. (*b*) One showed no R.B.C.s at any time.

Six men with negative Papanicolaou smears showed bladder tumours on first cystoscopy (false negatives). (*a*) Four were cystoscoped because of excessive R.B.C.s. (*b*) Two showed only occasional R.B.C.s and had symptoms .

Sixty-two cases of bladder tumour and one case of carcinoma of the prostate were detected.

Ten men had positive Papanicolaou smears, but no bladder tumours have so far been discovered on cystoscopy (false positives). (*a*) Three showed R.B.C.s sufficient in themselves to be an indication for cystoscopy. (*b*) One had slight symptoms. (*c*) Six showed only occasional R.B.C.s.

Eighteen men had negative Papanicolaou smears and no tumour on cystoscopy (true negatives). They were cystoscoped because (*a*) 11 showed R.B.C.s sufficient to be an indication for cystoscopy, and (*b*) seven had both R.B.C.s and symptoms.

Ninety-one men were cystoscoped.

Discussion

During the five years under review, 51 (76·1%) out of 67 men with positive smears had bladder tumours on first cystoscopy and the figure becomes 57 (85·1%) out of 67 when the five " probably true positives " and the carcinoma of prostate are included.

Men with negative Papanicolaou and wet smears were presumed to be clear of tumours in the absence of symptoms and were not submitted for cystoscopy. The fact that in the five years all the tumours found were at an early stage in their development on first examination suggests that this view is reasonable. In six cases it was found that a tumour was present when a Papanicolaou smear was negative but all of these had an excess of red blood cells or had symptoms.

Tables 2 and 3 show the results of the application of the wet smear technique and the Papanicolaou technique to the urine of the 91 men who were cystoscoped.

Tables 2 and 3 show that in applying the wet smear technique to the urine of 88 of the men there were 25 (28·4%) false negatives and 20 (22·7%) false positive results whereas the Papanicolaou technique in 91 cases yielded only six (6·6%) false negative and 10 (11·0%) false positive results. From these data it can be concluded that the latter technique is superior as a diagnostic measure. In fact, as a result of the Papanicolaou technique 25 men were sent for investigation and a tumour detected before the onset of microscopic haematuria or any other indication that a tumour was present.

TABLE 2
WET SMEAR RESULTS

Cystoscopy	Red Blood Cells or Symptoms		Total
	Positive	Negative	
Tumour present	34	25	59
No tumour found	20	9	29
Total ..	54	34	88*

* In three cases no wet smear tests were done.

TABLE 3
PAPANICOLAOU SMEAR RESULTS

Cystoscopy	Papanicolaou Test		Total
	Positive	Negative	
Tumour present	57*	6	63
No tumour found	10	18	28
Total ..	67	24	91

* One case of carcinoma of prostate.

False Positive Results.—When cells with malignant characteristics are present in the urine and no growth is found anywhere in the urinary tract, the result is regarded as a false positive. At their first cystoscopy 15 men gave false positive results but five of them showed visible tumours on cystoscopic follow-up after five, 10, 11, 29, and 46 months respectively.

The following case is given as an example:—

Case 3.—This man was aged 58 when the tumour was found. He had been exposed to β-naphthylamine for eight years.

His urine was tested for R.B.C.s from 1936 onwards; occasional R.B.C.s had been apparent since 1950 but never of such significant number as to warrant cystoscopy. The Papanicolaou test showed malignant cells from March, 1953, onwards. He was investigated because of this in September, 1953, but no abnormality was seen except that on cystoscopy there was a little redness in a tiny area at the apex near the air bubble. Five weeks later, in October, 1953, the bladder looked more normal than previously and there was no change again in February, 1954. However, five months after this (July, 1954) and 10 months after the first cystoscopy a sessile tumour was found high up in the apex and a smaller tumour was seen near to the right ureteric orifice.

Clinically they appeared to be papillomata, but biopsy revealed them to be carcinomata.

The finding of apparently malignant cells in the urine before a tumour actually becomes visible is comparable to the finding by von Haam and Menzies (1953) of malignant cells in vaginal smears from laboratory animals some time before the gross appearance of experimentally induced carcinoma of the cervix uteri.

Chute and Williams (*loc. cit.*) in their series of cases were surprised at the number of carcinomata of the prostate that gave rise to positive smears in the sediment from ordinary voided urine, as distinct from that passed following prostatic massage. Amongst our cases one man with positive Papanicolaou smears was found to have a carcinoma of the prostate.

However, amongst our 10 false positive cases there are four men who have repeatedly shown malignant cells in the smear during the past two years and a further three who have shown similar findings recently. In none of these cases so far has a tumour been found on cystoscopy. The following case is a typical example:—

Case 4.—A man aged 44 had had slight exposure to bladder carcinogens, but had occasional attacks of cystitis with pain and dysuria.

He has had a few red blood cells persistently in the urine since 1949. The first Papanicolaou smears in April, 1952, were strongly positive, and all subsequent smears have remained so. He was cystoscoped in September, 1952, and again in February, 1954, but no abnormality was found either in the bladder or elsewhere in the urinary tract.

Masina (1952) in this country and Melicow (1952) and Melicow and Hollowell (1952) in America have noted that normal-looking epithelium taken from tumour-bearing bladders removed at total cystectomy when examined microscopically showed foci of cellular activity which closely resembled areas of tumour formation and other areas which they thought might in time develop into obvious growths. These observations may help to explain the continuous false positive smears from men with apparently normal bladders. It remains to be seen whether these men will develop tumours of the renal pelvis, ureter, bladder, or prostate later.

The remaining three false positive cases had renal calculus, urethral stricture, and haematuria following extensive burns. Ferguson (1949) points out that there are certain non-neoplastic conditions which produce cells almost identical to malignant ones and give rise to misinterpretation.

False Negative Results.—When a growth is found in the urinary tract of a man whose urinary sediment never shows the presence of tumour cells, the result is a false negative. There were six false negative results in our series, of which the following case is an example.

Case 5.—This man was aged 52 when the tumour was found. He had been exposed to α-naphthylamine for 19 years from 1935. His urine had been tested for R.B.C.s from 1936, and by the Papanicolaou technique from 1951. Although occasional R.B.C.s were noted they never reached sufficient numbers to warrant cystoscopy and the Papanicolaou results were always negative until he developed acute haematuria in September, 1954. Cystoscopy revealed a benign papilloma which was confirmed by biopsy.

In five of these cases the growth was clinically of a simple papillary type. On section, four were histologically benign, whilst in the fifth the biopsy material was unsatisfactory. In the sixth case a solid type of carcinoma covered with slough and calcareous deposit was present.

" Benign " Papillomata.—Benign papillomata appear to vary very much in the cells which they shed, and in some cases as Dean (1948) and Leadbetter (1955) point out, the exfoliated cells show no recognizable difference from the normal. Papanicolaou (*loc. cit.*) says such growths may be recognized by the presence of cuboidal and columnar cells often arranged in groups and clusters, sometimes showing a palisade formation, and he puts them in the category of Class II, reporting them as atypical but suggestive of benign papilloma. However, he says, " their occasional presence in cases in which there is no evidence of such a growth limits their diagnostic significance ", and also that " intermediate cell types from the prostate are also seen, some with a cuboidal or columnar form reminding one of cells exfoliated from a benign papillary growth ". McDonald (1954) says that it is exceedingly difficult to distinguish benign papillomata unless fronds of tissue are exfoliated, while Osborn (1953) observes that such fragments of tissue show little cellular variation. Other authors (Chute and Williams *loc. cit.*; Schmidlapp and Marshall, 1950; Deden, *loc. cit.*) have come to the conclusion that cells from benign papillomata do not usually deviate from the normal sufficiently to permit a diagnosis and that amongst their cases their false negative results were mostly such tumours.

Our experience of these benign tumours is of considerable interest. Fifty-six men had bladder tumours in association with the exfoliation of abnormal cells. In 53 of them these cells had apparently malignant characteristics and in the other three only clumps of " benign papilloma "

cells were seen. Yet, of these 56 men, 29 had clinically benign papillomata; 15 of these were confirmed by biopsy, four proved to be malignant on biopsy, and 10 were treated without biopsy. Twenty-seven men had clinical carcinomata; 22 were confirmed by biopsy.

Thus, 26 out of 29 men with clinically benign papillomata had apparently malignant cells in the urine, yet only four out of 19 of these tumours were found to be malignant on biopsy. Although it is tempting to suggest that malignant changes were already taking place in these tumours, such an assumption would lead to an abnormally high incidence of malignancy amongst them. No satisfactory explanation is available to explain the finding of cells with apparently malignant characteristics in the urine from such a high proportion of bladders containing benign tumours. In our experience it has not been possible to predict the precise nature of the tumours from the appearance of the exfoliated cells. Nevertheless, these results show that, contrary to many opinions, the Papanicolaou technique is capable of detecting a significant proportion of benign papillomata.

Use of Papanicolaou Technique in Follow-up of Treated Cases.—As there is a continuing liability for further tumours to appear in persons who have been treated for a bladder tumour, it is essential that cystoscopic reviews should be continued for life. It was hoped, when the Papanicolaou technique was introduced, that it could be substituted for at least some of these review cystoscopies. We have applied this test to a group of 42 men who have had tumours treated (Table 4).

TABLE 4

RESULTS OF 225 REVIEW CYSTOSCOPIES OF 42 MEN COMPARED WITH RESULTS OF SMEARS BEFORE EACH CYSTOSCOPY

Papanicolaou Smear Results	Cystoscopy			Total
	Negative	Suspicious	Positive	
Negative	83	10	20	113
Suspicious	19	20	4	43
Positive	27	27	15	69
Total	129	57	39	225

From this it appears that dependence cannot be placed on the result of Papanicolaou smears from men with a previous history of a treated tumour. Some individuals showed complete agreement all the time, while others continually showed false positive or false negative results. At the present stage of our investigation it can therefore only be said that the stained smear technique is unreliable in reviewing established cases. It is too early yet to know whether these false positive smears have any prognostic significance.

Conclusions

Our experience over the past five years has shown that the Papanicolaou technique can be successfully used as a method of screening the urine of an industrial population. This confirms the suggestions of Case (unpublished, 1949) and of Cromwell and Papanicolaou (1952) that cytological examination of the urine would be of value in detecting industrial bladder tumours. The most important advantage of the method is its ability to indicate the presence of a tumour at a very early stage of its development, often before any presenting symptoms or other urinary abnormalities have given an indication of its presence. Poole-Wilson (1953) observes that on account of routine medical examination in industry occupational bladder tumours tend to be seen in an earlier stage than those arising spontaneously.

To obtain the best results both the Papanicolaou and the wet smear technique should be employed together. On the other hand, wet smears of concentrated deposit can be examined for epithelial cells, and a Papanicolaou smear only made and examined if such cells are seen. If the urine is acellular much time and trouble can be saved in this way without a significant loss of efficiency. By this means it is possible to maintain a much more comprehensive and frequent check on large industrial populations than can be achieved by the use of routine cystoscopy. It is also possible to include considerable groups of workers whose chance of tumour development may only be remote.

Routine annual cystoscopy of persons with high risk is claimed to be practicable abroad. If it had been used as a screening method on this population it would have involved at least 8,000 cystoscopies in five years compared with the 91 carried out for us. The fact that early diagnosis was achieved in our cases leads us to believe that the techniques we have described offer very considerable advantages. We consider that they are indispensable, if all necessary care is to be given to workers in any factory where a hazard of industrial bladder tumours exists.

Summary

A description is given of cytological methods of achieving early diagnosis of occupational bladder tumours. The results obtained by examining the urine of some 1,800 workers for the presence of microscopic haematuria and by the Papanicolaou technique are reported together with the cystoscopic findings amongst 91 men.

The advantages and disadvantages of the two techniques are discussed.

It is concluded that the Papanicolaou technique offers considerable advantages in the diagnosis of benign and malignant tumours of the bladder, and

that this, coupled with the examination of urine for red blood cells, is the method of choice for screening an industrial population with a high risk of such tumours.

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REFERENCES

Aboulker, P., Gaultier, M., Benguigui, M., and Smagghe, G. (1949). *Arch. Mal. prof.*, **10**, 370.
Billiard-Duchesne, J. F. (1949). Proc. Ninth int. Congr. industr. Med., London, 1948, p. 507. Wright, Bristol.
Case, R. A. M., Hosker, M.E., McDonald, D. B., and Pearson, J. T. (1954). *British Journal of Industrial Medicine*, **11**, 75.
——, and Pearson, J. T. (1954). *Ibid.*, **11**, 213.
Chute, R., and Williams, D. W. (1948). *J. Urol.*, **59**, 604.
Crabbe, J. G. S. (1952). *Brit. med. J.*, **2**, 1072.
Cresdee, W. C., Guest, D., and Wignall, T. H. (1934). Unpublished.
Cromwell, H. A., and Papanicolaou, G. N. (1952). *Arch. industr. Hyg.*, **5**, 232.
Dean, A. L. (1948). *J. Urol.* (*Baltimore*), **59**, 614.
Deden, C. (1954). *Acta radiol.* (*Stockh.*), Suppl. **115**, 18.
Ferguson, J. H. (1949). *Cancer*, **2**, 845.
Gehrmann, G. H. (1934). *J. Urol.* (*Baltimore*), **31**, 126.
——, Foulger, J. H., and Fleming, A. J. (1949). Proc. Ninth int. Congr. industr. Med., London, 1948, p. 472.
Goldblatt, M. W. (1949). *British Journal of Industrial Medicine*, **6**, 65.
Graham, R. M. (1950). *The Cytologic Diagnosis of Cancer* (Vincent Memorial Hospital), p. 208. Saunders, Philadelphia.
Gross, E. (1940). *Angew. Chem.*, **53**, 368.
Haam, E. von, and Menzies, P. (1953). *Proc. Amer. Ass. Cancer Res.*, **1**, 22.
Hope, J., and Scott, T. S. (1936). Unpublished.
Leadbetter, W. F. (1955). "*CA.*" *Bull. of Cancer Prog.*, **5**, 131.
McDonald, J. R. (1954). *Amer. J. clin. Path.*, **24**, 684.
Maio, G. di (1937). *Arch. ital. Urol.*, **14**, 283.
—— (1949). Proc. Ninth int. Congr. industr. Med., London, 1948, p. 476.
Masina, F. (1952). *Brit. J. Urol.*, **24**, 344.
Melicow, M. M. (1952). *J. Urol.* (*Baltimore*), **68**, 261.
——, and Hollowell, J. W. (1952). *Ibid.*, **68**, 763.
Müller, A. (1951). *Helv. chir. Acta*, **18**, 1.
Nassauer, M. (1920). *Frankfurt Z. Path.*, **22**, 353.
Oppenheimer, R. (1920). *Zbl. Gewhyg.*, **8**, 105.
Osborn, G. R. (1953). *Applied Cytology*, p. 146. Butterworth, London.
Papanicolaou, G. N. (1947). *J. Urol.*, **57**, 375.
——, (1954). *Atlas of Exfoliative Cytology*, pp. 13, 38, and 39. (Commonwealth Fund), Harvard University Press, Cambridge. Mass.
——, and Marshall, V. F. (1945). *Science*, **101**, 519.
Poole-Wilson, D. S. (1953). In *Modern Trends in Urology*, p. 401, ed. E. W. Riches. Butterworth, London.
Rofe, P. (1955). *J. clin. Path.*, **8**, 25.
Sawaya, M., Sandin, D., and Almeida, L. C. de (1954). *J. Amer. med. Ass.*, **154**, 931.
Schmidlapp, C. J., and Marshall, V. F. (1950). *N.Y. St. J. Med.*, **50**, 56.
Scott, T. S. (1952). *British Journal of Industrial Medicine*, **9**, 127.

Brit. J. industr. Med., 1956, **13**, 277.

THE WHITE CELL COUNT AND EXPOSURE TO RADIATION HAZARDS

THE SIGNIFICANCE OF LEUCOCYTE "WARNING" AND "REJECTION" LEVELS IN THE YOUNGER AGE GROUPS

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From time to time the medical officers examining new entrants to the Atomic Energy Research Establishment (A.E.R.E.) receive the impression that there is an undue proportion of low blood counts in the "apprentice age" personnel. This appears, in general, to take the form of a neutropenia, which may, in certain cases, throw doubt on the suitability of an applicant for work which might involve exposure to radiation. It seemed appropriate, therefore, to investigate the blood counts of all age groups to find out whether there was any statistical evidence to support this impression.

Method

Two sets of figures, based on estimates of the lower limits of normal, have been adopted at A.E.R.E. to act as a guide to doctors carrying out pre-employment medical examinations, one setting a "warning" level of blood count and the other a "rejection" level.

	Warning Level ($mm.^3$)	Rejection Level ($mm.^3$)
Leucocytes	4,500	3,000
Neutrophils	3,000	2,000
Lymphocytes	1,000	750

A candidate having a count at the former level would be accepted for employment, but would be exposed to radiation hazard only if and when it had been found that this was, in fact, his physiological level and that clinical signs of damage to or deficiency in the haemopoietic tissues were absent: a candidate with counts at or below the rejection level would be considered unsuitable for employment in an atomic energy establishment.

It has been shown by Chamberlain, Turner, and Williams (1952) that the first, or pre-employment count, is not the most reliable count on which to base a statistical investigation as it tends to be inflated by emotional factors. However, in this instance, it was considered to be the appropriate figure to use, as it is from this evidence that the medical officer has to deduce whether an applicant is, or is not, suitable for appointment.

The data used consisted of the first counts of all potential new entrants examined during the two-year period July 1, 1952, to June 30, 1954; these numbered 1,897.

Results

The numbers and percentages of low counts for each type of cell in each age group are shown in Table 1.

TABLE 1

NUMBERS AND PERCENTAGES OF PRE-EMPLOYMENT COUNTS BELOW "WARNING" AND "REJECTION" LEVELS

Age Group	No. in Age Group	Leucocytes		Neutrophils		Lymphocytes	
		No. Below	% of Age Group Below	No. Below	% of Age Group Below	No. Below	% of Age Group Below
Below Warning Level							
16-19	340	12	3·5	83	24·4	2	0·6
20-29	735	19	2·6	119	16·2	6	0·8
30-39	403	3	0·7	47	11·7	1	0·3
40-49	248	7	2·8	27	10·9	1	0·4
50-59	128	3	2·3	18	14·1	0	0
60-69	43	2	4·6	6	14·0	0	0
Totals	1,897	46	2·4	300	15·8	10	0·5
Below Rejection Level							
16-19	340	0	0	9	2·6	0	0
20-29	735	0	0	10	1·4	2	0·3
30-39	403	0	0	2	0·5	1	0·3
40-49	248	0	0	4	1·6	0	0
50-59	128	0	0	2	1·6	0	0
60-69	43	0	0	3	7·0	0	0
Totals	1,897	0	0	30	1·6	3	0·2

These results show that low neutrophil counts would account for a greater number of rejections or "provisional" acceptances than would low lymphocyte counts: of the totals for all age groups 15·8% show warning level "neutropenia" as against 0·5%

" lymphopenia ", and 1·6% show rejection level " neutropenia " compared with 0·2% " rejection " level " lymphopenia ". Furthermore, the age group showing the highest number of counts below warning level, is, as was suspected by the medical officers, the 16-19-year-olds. Although the rejection rate in all groups is small, Table 1 shows that, over the range 16-60 years, the apprentice age group has a higher rejection rate than the older age groups: the 60-70-year-olds (a relatively small group) have the highest rejection rate (7%). There are no rejections based solely on leucocyte counts, and only 0·2% of all ages based on lymphocyte counts.

Whitby and Britton (1946) and various other workers, including Garrey and Bryan (1935) and Kolmer and Boerner (1945), state that the mean leucocyte count shows a tendency to fall with age over the years covering infancy to about 12 to 15 years, after which it tends to remain stationary, the effect of increased age being negligible (Gabbert, Hutaff, and Harrell, 1947). If this is the case it would be expected that in a normal working population the proportion of individuals with counts below rejection and warning levels would be the same for all age groups. Thus if the expected numbers below warning and rejection levels respectively for each age group are estimated on the assumption that the proportion of individuals with low counts would be the same for all age groups and those expected numbers are compared with the observed numbers, a χ^2 test can be made, results of which would not be expected to be significant. Total leucocyte counts showed good agreement between observed and expected numbers below warning level ($P = 0{\cdot}25$): there were no leucocyte counts below rejection level. In the case of neutrophils, however, at warning level χ^2 is highly significant ($P < 0{\cdot}001$), which is due in large measure to the excess of observed over expected figures in the youngest age group. Agreement is reasonably good at neutrophil rejection levels ($P \sim 0{\cdot}1$), although here again there is an excess of observed over expected figures in the youngest age group. The numbers of lymphocyte counts below warning and rejection levels were too small to apply the χ^2 test.

The tendency towards low neutrophil counts in the youngest group is reflected in the level of the mean counts of that group when compared with those for the older groups (Table 2). The levels of lymphocyte counts are approximately the same for all groups.

It was considered possible (although unlikely) that the high proportion of " neutropenics " in the youngest age group might be due to absence of emotional effects in younger personnel; accordingly a further survey on similar lines and covering the same period of time was made based on the second counts of randomly selected personnel not exposed to radiation. Details are given in Tables 3A and B.

TABLE 2

MEAN COUNTS OF NEW ENTRANTS ACCORDING TO AGE GROUPS (per mm.³)

Age Group	No.	Leucocytes		Neutrophils		Lymphocytes	
		Mean	S.E.	Mean	S.E.	Mean	S.E.
16-19	340	7,728	125	4,277	103	2,631	44
20-29	735	7,950	85	4,659	69	2,495	30
30-39	403	8,670	141	5,301	119	2,597	43
40-49	248	8,510	162	5,028	117	2,659	54
50-59	128	8,125	238	4,590	165	2,662	82
60-69	43	8,819	438	5,122	338	2,840	159
Total	1,897	8,168	57	4,761	46	2,581	19

TABLE 3A

NUMBERS AND PERCENTAGES OF COUNTS BELOW WARNING AND REJECTION LEVELS AT SECOND BLOOD COUNT

Age Group	No.	Leucocytes*		Neutrophils				Lymphocytes*	
		Warning Level		Warning		Rejection		Warning	
		No. Below	% of Age Group Below	No. Below	%	No. Below	%	No. Below	%
16-19	109	3	2·75	27	24·77	5	4·59	0	0
20-29	196	6	3·06	55	28·06	5	2·55	1	0·51
30-39	260	10	3·85	68	26·15	6	2·31	1	0·38
40-49	81	0	0	16	19·75	3	3·70	0	0
50-59	120	7	5·83	24	20·00	3	2·50	2	1·67
60-69	80	1	1·25	15	18·75	1	1·25	0	0
Total	846	27	3·19	205	24·23	23	2·72	4	0·47

* There were no leucocyte or lymphocyte counts below rejection level.

TABLE 3B

MEAN OF SECOND BLOOD COUNTS BY AGE GROUPS

Age Group	No.	Leucocytes		Neutrophils		Lymphocytes	
		Mean	S.E.	Mean	S.E.	Mean	S.E.
16-19	109	7,512	180	3.892	133	2,804	79
20-29	196	7,589	146	4,054	98	2,704	59
30-39	260	7,921	149	4,327	125	2,801	55
40-49	81	8,300	322	4,553	225	2,838	101
50-59	120	7,965	235	4,596	175	2,604	80
60-69	80	8,132	291	4,425	199	2,813	109
Total	846	7,854		4,277		2,756	

On the basis of second counts, a much higher percentage (ranging from 18 to 28) of neutrophil counts of all age groups falls into the warning category (Table 3A); similarly, although the figures are of more reasonable proportions (from 2% to 4%), an increase in the number of neutrophil counts at rejection levels is observed. Furthermore, the numbers of counts falling below warning or rejection levels now tend to be the same for all age groups. However, in the 16-19 age group the percentage at warning level remains the same as in the earlier estimate. Applying the χ^2 test as before, good

agreement is found between expected and observed figures for each age group, the figures for χ^2 not being significant for all types of cell at both levels.

Reference to Table 3B shows that, as was demonstrated in earlier work at A.E.R.E. (Chamberlain *et al.*, 1952), the means of second counts are, at all age levels, lower than those of first counts. However, the relative differences between the mean counts of the age groups remain substantially the same, *i.e.*, the lowest age groups have the lowest counts.

A further line of investigation to account for the high incidence of low neutrophil counts was suggested by evidence (Chamberlain *et al.*, 1952) that a seasonal variation occurs in mean counts, the lowest levels being reached in the quarter from July 1 to September 30. It would be expected that a high proportion of the 16-19 age group would take up employment for the first time during this period which is coincident with the end of the school year. This being so it would follow that a higher proportion of blood counts would be performed on this group than on older groups at the time of year when the count is known to be at its lowest. In order to test this hypothesis an estimate was made of the distribution by age and season of 5,687 new entrants during the years 1949-54, and also of the 1,897 new entrants here under consideration. It was found that approximately 70% of the 16-19-year-olds take up employment in the later half of the year, whereas distribution of the older age groups is spread more evenly throughout the year.

There remained the further possibility that the time of day during which the counts were made might affect the level of count. It has been shown by Shaw (1927) and confirmed at A.E.R.E. (Chamberlain *et al.*, 1952) that the neutrophil count is lowest in the morning, rising to a maximum in the late afternoon. Thus, if a greater proportion of counts was made on younger entrants than on older entrants in the morning a bias towards low counts in the former group would be imparted. Accordingly the counts of all new entrants for the year 1954 were analysed by time of count and age group: the results, shown in Table 4, give little support to this hypothesis.

TABLE 4

DISTRIBUTION OF NEW ENTRANTS (1954) BY AGE GROUP AND TIME OF COUNT

Time	8 a.m.-10 a.m.	8 a.m.-1 p.m.	1 p.m.-5 p.m.	No. in Age Group
Age Group	% of Age Group	% of Age Group	% of Age Group	
16-19	52·45	66·24	33·76	154
20-29	45·16	64·08	35·92	465
30-39	49·08	61·53	38·47	273
40-49	66·25	71·88	28·12	160
50-59	72·63	82·11	17·89	95
60-69	78·79	90·91	9·09	33
				1,180

It will be observed that morning counts occur with greater frequency in the older age groups than in the younger age groups, although of the three younger decades the apprentice age group shows a slightly higher percentage of early counts.

Discussion

There is no doubt, on the basis of the standards laid down at A.E.R.E., that there is a higher proportion of individuals in the apprentice age group than in older age groups with pre-employment white cell (primarily neutrophil) counts below warning and rejection levels. Whilst there is little difference between all age groups in the number of " warnings " and " rejections " based on lymphocyte counts, and slightly more when based on leucocyte counts, there is a considerable difference between the 16-19-year-olds (24%) and the higher age groups (11%-16%) when the pre-employment neutrophil count is considered. It is difficult to find a satisfactory explanation of this phenomenon, particularly as, as mentioned earlier, the consensus of opinion appears to be that adult levels of counts are reached between the ages of 12 and 15 years. There is no information in the literature to suggest that a tendency towards low neutrophil counts exists during this period (16-19 years) of growth. Abbott, Ahmann, and Overstreet (1939), working with college students, women, and children in rural schools, observed that vitamin A deficiency appears to produce a slight leucopenia, chiefly affecting the neutrophils, but no evidence is available regarding the nutritional status of the population here under review to suggest that this might account for the low neutrophil counts in the youngest group. Nor can they be accounted for by the time of day at which counts are made. In fact, if this were the predominating factor affecting level of counts, it would be expected from the results in Table 4 that the lowest counts would be found in the higher age groups.

There is a possibility that the physiological response to emotion associated with and raising the level of first blood counts may be less in the apprentice age group than in older groups. Some support is lent to this theory by the results of the investigations on second counts reported in Table 3. This shows that although the mean of all second counts is lower than the first, the effect is less marked in the youngest group. Furthermore, the percentage of individuals below warning level in the youngest group remains the same for both first and second counts, but is increased in the older age groups.

A possible explanation of the excess of low counts in the apprentice age group is likely to be found in

the fact that the majority of its members begin employment and have their first count during the period of the year in which blood count levels are normally at their lowest. This means that any comparison made with other age groups, whose date of entry is spread out more evenly over the whole year, is likely to show a bias towards lower counts in this group. Furthermore, the depressing seasonal effect would be reflected in the mean of subsequent counts, when carried out on an annual basis.

It appears to the writer that, in the light of the results of this investigation, the use of a figure of 3,000 neutrophils per mm.^{3} as a warning level is unrealistic. Its use implies that, on the basis of a first count, 16%, or on the basis of a second count, 24%, of candidates would require careful medical supervision when considerations for exposure to radiation hazards arose. This, in what is assumed to be a cross-section of a normal healthy working population, seems to be an unduly high proportion; it would be expected that the findings for neutrophils would be of a similar order to those of leucocytes and lymphocytes and not five to eight times greater as is now the case. It is suggested therefore that a lower figure should be adopted. If a figure of 2,500 per mm.^{3} were used distribution of "warnings" between age groups would be as follows for first and second counts (Table 5).

TABLE 5
NUMBER AND PERCENTAGES OF NEUTROPHIL COUNTS BELOW A WARNING LEVEL OF 2,500 CELLS PER mm^3

Age Group	First Count			Second Count		
	Neutrophils	No.	%	Neutrophils	No.	%
16-19	340	36	10·58	109	14	12·84
20-29	735	45	6·12	196	23	11·73
30-39	403	22	5·46	260	28	10·76
40-49	248	13	5·24	81	6	7·41
50-59	128	11	8·59	120	13	10·83
60-69	43	3	6·97	80	7	8·75
Total	1,897	130	6·85	846	91	10·75

The figures are still considerably higher than comparable figures for leucocytes and lymphocytes, particularly in the 16-19-year group, the warning rates being 7% and 10% for all groups and for the 16-19 age group respectively. A further reduction of 500 in warning level would bring the figures down to those of the present rejection level.

The adoption of a figure of 2,500 neutrophils per mm.^{3} would still be above the lower limits of the 95% range quoted by various authors:

	Neutrophils	95% Range
A.E.R.E. (1951) pre-employment	3,098	2,250-8,200
A.E.R.E. (1952-54)	1,897	2,100-9,500
Blackburn (1947)	642	856-7,352
Osgood *et al.* (1939)	269	1,500-7,300

Russ (1943) lists the lower limits of neutrophil counts regarded by 16 heads of hospital departments as incompatible with continuance of radiological work. Of these seven range from 2,000 to 2,500 and nine from 3,000 to 4,000 cells per mm.^{3} Robertson-Smith (1951) stated that the lower limit of normal for personnel working with radiation was changed in his establishment from 3,000 to 2,000 neutrophils per mm.^{3}, as it was found that a considerable number of counts below 3,000 per mm.^{3} occurred in unexposed personnel.

The findings from this investigation suggest that, in order to avoid undue discrimination against the youngest age group as a result of low neutrophil counts, more latitude might be exercised regarding acceptable levels of count, so long as the clinical picture reveals no indication of haemopoietic deficiency. Haematological control could be maintained in this age group by taking blood counts at intervals sufficiently close to render it possible to acquire some information on the individual's basic norm.

Summary

An analysis has been made of the blood counts of 1,897 new entrants during the period July 1, 1952, to June 30, 1954, to determine the number with counts below "warning" and "rejection" levels in various age groups.

The number of individuals with neutrophil counts below these levels was found to be higher in the 16-19-year age group than in the older groups. There were also more warnings and rejections in all groups attributed to low neutrophil counts than to low leucocyte or lymphocyte counts.

An investigation into the distribution of age groups according to season of the year revealed that a higher proportion of apprentice age personnel began employment at the end of the school year, which coincides with the season at which blood counts are known to reach their lowest level.

The adoption of lower standards for warning and rejection levels of neutrophil counts is recommended.

REFERENCES

Abbott, O. D., Ahmann, C. F., and Overstreet, M. R. (1939). *Amer. J. Physiol.*, **126**, 254.
Blackburn, C. R. B. (1947). *Med. J. Aust.*, **1**, 525.
Chamberlain, A. C., Turner, F. M., and Williams, E. K. (1952). *Brit. J. Radiol.*, **25**, 169.
Gabbert, W. R., Hutaff, L. W., and Harrell, G. T. (1947). *Geriatrics*, **2**, 96.
Garrey, W. E., and Bryan, W. R. (1935). *Physiol. Rev.*, **15**, 597.
Kolmer, J. A., and Boerner, F. (1945). *Approved Laboratory Technic.*, 4th ed. Appleton-Century Co., New York.
Osgood, E. E., Brownlee, I. E., Osgood, M. W., Ellis, D. M., and Cohen, W. (1939). *Arch. intern. Med.* **64**, 105.
Robertson-Smith, D. (1951). Atomic Energy Research Establishment Med./R. 931.
Russ, S. (1943). *Brit. J. Radiol.*, **16**, 6.
Shaw, A. F. B. (1927). *J. Path. Bact.*, **30**, 1.
Whitby, L. E. H., and Britton, C. J. C. (1946). *Disorders of the Blood*, 5th ed. Churchill, London.

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DERMATITIS IN COAL-MINERS

BY

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The Size of the Problem

Occupational skin disease in coal-miners in Great Britain is an important medical and economic problem. The report of H.M. Chief Inspector for Mines (1950) shows the steady increase in the number of certificates of disablement for industrial dermatitis given under the Workmens Compensation Act from 402 in 1940 to 1,650 in 1947, and 1,588 up to July 5, 1948. From that date the certificates given for dermatitis under the National Insurance (Industrial Injuries Prescribed Diseases) Regulations, 1948, continued to increase to 3,100 in 1949, the last year for which figures are given in this report. These statistics cover all persons employed in the coal-mining industry, reaching a peak of 750,300 in 1944, but falling to 747,000 by the following year.

During the period 1940-44 the dermatitis certification rate per 1,000 workers employed underground in Great Britain rose from 0·7 to 5·1 and in the South Western Region from 0·6 to 6·6. The dermatitis certification rate for all employees for the years 1946-50 can be calculated from the total number of employees given in the report of the Chief Inspector of Mines, and shows an increase from 2·4 per 1,000 total employees in 1946 to 4·2 per 1,000 in 1949. Unfortunately, comparable figures for underground workers only to give a more exact picture are unobtainable.

Squire, Cruickshank, and Topley (1950) were able to show that in the engineering industry the actual incidence of dermatitis is higher than the certification rate indicates as many workers do not report the less severe attacks. The same is certainly true of the mining industry, and it is our experience that some miners continue at work even with extensive dermatitis. The statistics quoted, therefore, define the extent of the economic problem of industrial dermatitis but underestimate the size of the medical problem, for which no figures are yet available. Squire and his colleagues also drew attention to the fact that more certificates for dermatitis had been issued in all industries, even in those in which no technological changes have been introduced. They suggested that the increase might be more apparent than real and might be due to a greater willingness on the part of the worker to stop work as a result of improved social security.

Although it is the opinion of many practitioners in coal-mining districts that there has been a real and substantial increase in the incidence of dermatitis, there is no proof that such is the case and the actual incidence of dermatitis is unknown.

The Literature

The diseases of miners have attracted the interest of medical men from the earliest times. The history of miners' diseases has been comprehensively reviewed by Rosen (1943), but skin diseases in miners are rarely mentioned in the earlier literature. Ramazzini (1746) has two brief references. He refers to injury to the skin of the lower legs in those working in water, and also mentions what appears to be a form of skin ulceration. Incidental references to pustular eruptions are occasionally encountered but other diseases are rarely recorded. Thackrah (1832) makes no specific mention of skin diseases. Boëns-Boissau (1862), in his volume on the diseases and accidents of Belgian coal-miners, states specifically that skin diseases are less common in miners than one expects from the nature of their occupation. He devotes six pages to the skin and discusses ringworm, scabies, zoster, acne, bursitis, and eczema, but does not suggest that any is related to the occupation. The monograph of the Belgian, Kuborn (1863), mentions 36 affections of the skin in a group of 1,518 miners but gives no details.

The authoritative works on occupational skin disease of the present century devote little attention to miners. Prosser White (1915) gives only a very brief reference to pigmented scars. Schwartz, Tulipan, and Peck (1947) devote less space to miners and workers in related occupations than to the theatrical profession and motion picture industry.

Heymann and Freudenberg (1925) published a detailed statistical study of the morbidity and mortality of Ruhr miners, but he made no reference to dermatitis. A United States Public Health Service Bulletin (Flinn, Seifert, Brinton, Jones, and Franks, 1941) devoted to the health of soft-coal-miners is naturally mainly concerned with silicosis. " Other occupational hazards did not appear to be of significance . . . Miners' nystagmus, bursitis, and allied conditions were not observed." This negative evidence suggests that dermatitis in miners has become a more serious problem in recent years and that the incidence may differ from country to country.

Dowling and Brain (1934) described an outbreak of a widespread pustular eruption which affected about 100 miners in a hot pit.

Knowles (1944) investigated the factors influencing dermatitis in a group of nine pits in the Chesterfield area, employing 7,700 men. Fifty-six cases of dermatitis occurred in two years. The depths, wet and dry bulb temperatures, or humidity, did not influence the incidence, nor was it higher in wet pits than in dry. The importance of water, dust, trauma, and constitutional factors is emphasized but the number of cases was too small for any conclusions to be drawn as to the relative importance of the various factors.

Holčík (1952) of Czechoslovakia examined miners in pithead baths. He found tinea pedis in almost 50%, and more frequently in the younger miners, irrespective of the duration of employment. Furunculosis was present in 7%, occurring mainly during the first two years underground. High environmental temperatures and poor ventilation were contributory factors. Contact dermatitis was mainly due to trauma; the incidence is not mentioned and the clinical patterns are not described. Acne was apparently aggravated by mining. Psoriasis is stated to be uncommon—less than 0·89% were affected. Carrié (1951) discussed the increasing incidence of tinea infections in miners.

Sneddon (1951) drew attention to the long period at work (average 15 years in his 59 colliery workers) before dermatitis develops. He considered ageing of the skin to be an important factor in predisposing to dermatitis and suggests that the repeated washing which the miner cannot avoid may also be a contributory factor. Only two of his patients had an occupational dermatitis due to sensitization and in both cases the rubber lining of the pit helmet was responsible.

Atkins and Marks (1952) reported a careful investigation of beat disorders. They were able to demonstrate that the attacks usually resulted from the extension of a staphylococcal infection.

The Miner

The special working conditions inseparable from the occupation of mining have developed in the miner certain well-defined mental characteristics and the segregation of miners into sometimes isolated communities devoted almost exclusively to mining has accentuated the differences in outlook resulting from the occupation itself. Although improved transport facilities and the government-sponsored development of trading estates in mining districts are tending to break down these differences, the miner still retains many of his traditional attitudes.

The miner's relations with his employers have often been unhappy and for many years such improvements in his working conditions as he was able to obtain followed lengthy industrial disputes. Many of the older miners have known long years of unemployment and insecurity and probably a majority of the younger miners are the sons of such men.

Dickson (1936), writing of his impressions of a lifetime in general practice in a Scottish mining district, noted an increased incidence of peptic ulcer and nervous symptoms among miners. He suggested that the change from individual heaving at piece rates to the noisy monotonous mechanical cutting at shift rates might be in some way responsible. He noted a passive dissatisfaction with the work and insisted that " comfort " in its widest sense is necessary to maintain health.

Halliday (1948), acting as a medical referee under the National Health Insurance Act, made a special examination of 200 miners aged less than 45 and of 200 non-miners in the same age group. Sixty-four per cent. of the miners but only 38% of the non-miners were disabled by psychoneurotic or psychosomatic conditions. He pointed out that sepsis and inflammation of the skin were a cause of disablement 2·6 times more frequently in miners than in non-miners. In discussing those conditions recognized as of psychosomatic origin, he emphasizes, in addition to personal and economic problems, difficulties in the working environment and knowledge and fears of disease and injury as psychosocial barriers to recovery.

Heron and Braithwaite (1953) applied a small battery of objective tests to 184 colliery workers aged 40 to 50 (76 were working underground). They claim to have shown a greater degree of instability (" psychoneurotic handicap ") among underground workers than in surface workers.

Wiesel and Arny (1952) in a psychiatric study of coal-miners in the eastern Kentucky area describe

a " miner's syndrome " in the miner over 40, characterized by numerous somatic complaints, a passive dependent attitude, and an outstanding lack of anxiety with rationalizations based on having been exposed to " bad air " or hard work. The younger miner showed more conscious anxiety.

The significance of these observations and opinions is doubtful but it is certain that no study of any condition in the causation of which emotional factors may play some part can afford to ignore the psychosocial aspects of a highly specialized physical and emotional environment.

Skin Hazards of Coal-miners

The coal-miner is less exposed to specific chemical irritants than workers in many industries, but with increasing mechanization this hazard is assuming greater importance. Miners operating mechanical picks, cutters, and borers are in frequent contact with lubricating oils, and those engaged in maintenance cannot escape occasional contact with fuel oils. The blast of automatic picks sometimes produces contamination of the skin by oil under pressure. Pit props are often treated with creosote, but in some pits metal props are replacing the older wooden type. Men and boys engaged in cleaning and filling lamps are in contact with paraffin. A lime wash is freely used on the gallery walls. Some miners employ paraffin or other grease solvents to clean the hands after work. Many use bar alkali soap for washing.

In deep mines the temperature and humidity may be very high. However, both temperature and humidity can vary greatly in different sections of the same mine, according to the distance from the shaft and the efficiency of ventilation. The relative humidity does not vary directly with the temperature and some deep mines are dry. In others the relative humidity may reach 90%.

Since the introduction of water infusion of the coal face to suppress dust, maceration of the skin of the hands has become more frequent, but it was always common in those mines which were wet from the percolation of water through overlying strata. In some mines there may be several inches of ground water, of which the salt content is variable. Miners sometimes complain that the water in certain mines " stings " or " smarts ".

The miner's skin is subjected to trauma in a variety of ways. The hands and forearms are exposed to frequent injury, but the hazard is no greater than that of any heavy manual worker. Friction between the skin and the top of the boot, the gaiters, the belt, the back of the helmet, the battery, and the battery straps may be great and the effect on the skin is accentuated when particles of coal or stone dust are rubbed into the skin in these sites.

Apposed skin surfaces are inevitably rubbed together in any heavy occupation, but the miner may be compelled to work for long periods in unusual postures which may bring into close apposition such surfaces as the forearm and the thigh. Since the introduction of pithead baths in many collieries, some miners wear the same working clothes for too long and their clothes may become harshly abrasive from impregnation with coal dust and oil. Socks in this state may well be a contributory factor in dermatitis of the lower leg and foot. Some miners, still influenced by old superstitions, wear a body belt of coarse wool or do not wash the small of the back. Allergic sensitization to clothing is uncommon, but occasionally some component of the boots or the rubber helmet band is responsible.

It is not known whether the miner's relative lack of exposure to sun is of any significance in making him more susceptible to dermatitis.

Comparison of Dermatitis in Miners and Non-miners

As a preliminary to a planned investigation into skin disease in miners, the clinical notes of some 103 miners (first series) referred for examination by the Ministry of Pensions and National Insurance were examined and compared with those of 80 patients (second series) employed in other industries in South Wales similarly referred.

It was found possible to arrange the incidence of skin disease in the two groups as follows:— (1) Non-occupational, *e.g.*, pyogenic infections such as impetigo, psoriasis, seborrhoeic dermatitis, etc.; (2) occupational or aggravated by occupation; (3) doubtful, where occupational irritation could not be completely excluded, *e.g.*, pompholyx, atopic eczema, folliculitis.

Table 1 relates the incidence to age, and Table 2 shows the incidence of clinical pattern related to age and duration in the two groups. (In this context

TABLE 1
AGE INCIDENCE

	Under 19	20-29	30-39	40-49	50-59	60-69	Total
First series: 103 *miners*							
Non-occupational	1	2	3	2	1	0	9
Occupational	0	5	22	12	20	10	69
Doubtful	0	4	3	3	4	3	17
Tinea pedis	1	1	1	2	2	1	8
Second series: 80 *non-miners*							
Non-occupational	3	8	7	7	6	2	33
Occupational	1	3	7	12	14	8	45
Doubtful	0	1	0	0	0	0	1
Tinea pedis	0	0	0	0	0	0	0

TABLE 2
DISTRIBUTION OF CLINICAL PATTERNS OF OCCUPATIONAL SKIN DISEASE WITH AVERAGE AGE AND DURATION IN MINERS AND NON-MINERS

Site	Average Age		Average Duration	
	Miners	Non-miners	Miners	Non-miners
Hands	40	45	2 yr.	1 yr.
Hands, forearms	49	54	4½ mth.	4½ mth.
Groins, inner thighs, and calves	46	56	5 yr.	10 mth.
Lower legs	50	—	2 yr. 5 mth.	—
Feet and ankles (excluding tinea pedis)	40	47	1 yr. 10 mth.	4 yr. 3 mth.

" duration " is the time during which the patient was assessed.) Figures for tinea pedis are included in Table 1 since it is accepted for injury benefit in miners using pithead baths.

Greatly differing clinical patterns are seen in the two groups, and all these differences are shown in Fig. 1. Oil folliculitis was seen in one miner and three non-miners and there were two cases of chloracne in non-miners.

The figures confirm the experience of others that most cases occur in the 30 to 50 age-groups, but a further peak in the sixth decade occurs in miners (Nils and Skog, 1953). The recognized high incidence between 45 and 55 years of age has been attributed with little supporting evidence to ageing of the skin. MacCormac (1937) showed a precisely similar curve of incidence in non-occupational eczema.

Accepting the necessary case selection it seems that dermatitis in miners is more common on the lower legs, groins, and thighs than in other sites, whilst in other industries the hands and forearms are more often affected. Squire and others (1950) showed that most cases of dermatitis in the light engineering industry originate on the hands and forearms. The figures of long duration underline the chronic nature of the condition.

These facts stimulated a fuller statistical investigation into the natural history of dermatitis in coal-miners of South Wales.

Planned Statistical Investigation

A proforma was prepared for punch card analysis in consultation with a statistician.

The material consisted of Glamorgan miners and a few from Monmouthshire referred to hospital as out-patients. They were examined by three dermatologists separately, or by two working together. Of 70 proformas completed, only 53 were found suitable for analysis, made up of 33 occupational and 20 non-occupational cases. There were too many essential omissions from the remainder for them to be useful.

More than half of the cases of occupational

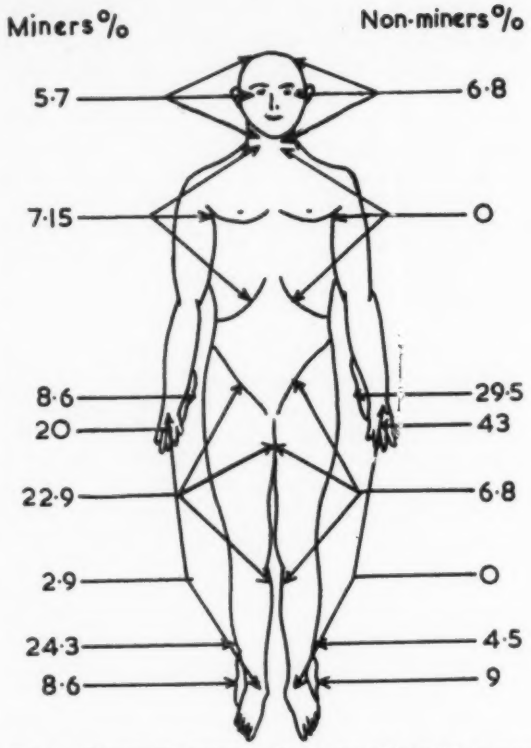

FIG. 1.—Diagram illustrating the distribution of dermatitis in miners and non-miners.

dermatitis occurred in the 40-59 age groups, the peaks of non-occupational cases being in the third and fifth decades.

Distribution of Dermatitis.—The observations of earlier authors were confirmed, as in 16 patients the feet, ankles, or lower legs were first involved; in only nine did the dermatitis begin on the hands or forearms. In several it originated in more than one site. All were occupational cases.

Site of Origin of Dermatitis		Distribution at Time of Examination	
Feet	9	Feet and ankles	9
Lower legs	9	Lower legs	19
Thighs, buttocks	3	Thighs, buttocks	6
Trunk (belt area)	3	Trunk	1
Neck	2	Axillae and groins	2
Hands and forearms	9	Shoulders	4
Other sites	1	Hands and forearms	14
More than one site	3	Neck	6
		Face, scalp	2
		Generalized	1

Length of Employment as a Miner.—Twenty-six of 33 miners with occupational dermatitis had worked underground over five years and 15 over 20 years confirming Sneddon's (1951) observations. Since younger men are equally exposed to all

exogenous causes, contributory factors may include the altered reactions of the skin of the ageing miner, but little is known of the effects on the skin of prolonged exposure to irritants.

Duration of Present Attack.—The duration of the present attack was specified in 31 cases and averaged 11·3 months. In 13 it was less than three months, and in seven exceeded one year. The duration was usually greater in the older miner.

Absence from Work due to Dermatitis.—No fewer than 14 (42·4%) had lost over three months from the present attack (the term " attack " including all spells from recrudescences of first attacks). A quarter lost over one year in attacks. No correlation of duration of absence with age was found and may reflect a greater tendency of the older worker to remain at work through greater financial commitments. A reasonably accurate assessment of the total absence from work is not always easy to obtain and could only be recorded for 30 of the cases.

Total Time off Work from Present Attack		Total Absence from Work (All Attacks)	
None	3	None	3
Under 1 week	2	Under 1 month	3
2 wk.—1 mth.	4	1 mth.—3 mth.	5
1 mth.—3 mth.	9	3 mth.—6 mth.	4
3 mth.—6 mth.	3	6 mth.—1 yr.	8
6 mth.—9 mth.	6	1 yr.—2 yr.	4
1 yr.—2 yr.	4	Over 2 yr.	3
2 yr.—5 yr.	1		
Not specified	1		
Total	33		30

Medical Attention.—Fifty per cent. of 33 cases were referred to a dermatologist within three months of the onset of dermatitis and almost all saw their own doctors within a month. No information was provided of the proportion who remained at work. In seven cases the dermatitis had existed over a year and in 10 for three to nine months. Earlier specialist advice might reduce the overall period of incapacity. Fifteen patients were idle for over six months and three more were off work over two years from all attacks.

Suggested Causative Factors.—When asked the cause of their dermatitis 19 blamed " oil " and 12 " dust and water ".

The tendency among miners, as in other industrial workers, is to attribute all skin disease to occupation, and they are aware that oil is a recognized cause of dermatitis, and that dust and liquids are accepted causes under the National Insurance (Industrial Injuries) Act. Only in one case was oil, in fact, responsible. After our interest in sweating became known this was more frequently suggested by the miner as his own opinion. The dermatologists recorded trauma, friction, water, dust, and heat, as common causes.

Contributory Factors.—Secondary infection was the most important and over-treatment or drug sensitization less than anticipated. The assessment of emotional factors is particularly unreliable. In all cases of dermatitis of the lower leg hypostatic congestion from impaired venous circulation may be an important contributory factor. This is particularly so in the case of the older worker in whom it may prolong the course of a dermatitis initiated by external factors. The assessment of lesser degrees of impaired venous circulation presents many difficulties and we were not able to evaluate its importance in this preliminary investigation.

Summary

The number of cases annually certified as occupational dermatitis has increased steadily in almost all industries in recent years. This increase is very much greater in mining than elsewhere.

The increasing certification rate may or may not indicate an actual increased incidence.

The literature on skin disease in coal-miners is reviewed.

The known skin hazards of coal-mining are described.

Dermatitis in coal-miners affects mainly the same age groups as in other industries.

Dermatitis in coal-miners involves most frequently the lower legs and the thighs and groins and less often the hands and forearms compared with 70-90% involvement of hands and forearms in most other industries.

Dermatitis in coal-miners runs a long course, particularly when the groins, thighs, or lower legs are affected.

In only a small minority of cases can occupational dermatitis in coal-miners be attributed to specific irritants and sensitizers are very rarely responsible.

The patterns of dermatitis encountered in miners are consistent with the hypothesis that physical factors—heat, maceration with water, dust, small coal, and trauma—play major roles in their provocation and perpetuation. Soiled and dirty clothes may be important in association. Secondary infection is common and probably of clinical significance.

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References

Atkins, J. B., and Marks, J. (1952). *British Journal of Industrial Medicine*, 9, 296.

Boëns-Boissau, H. (1862). *Traité Pratique des Maladies, des Accidents, et des Difformités des Houilleurs*. Tircher, Brussels.

Carrié, C. (1951). *Z. Haut-u. GeschlKr.*, **10**, 48.
Dickson, D. E. (1936). *Edinb. med. J.*, **43**, 696.
Dowling, G. B., and Brain, R. T. (1934). *Brit. J. Derm.*, **46**, 215.
Flinn, R. H., Seifert, H. S. E., Brinton, H. P., Jones, J. L., and Franks, R. W. (1941). "Soft Coal Miners: Health and Working Environment." *Publ. Hlth Bull. (Wash.)*, No. 270.
Halliday, J. L. (1948). *Psychosocial Medicine*. Heinemann, London.
Heron, Alastair, and Braithwaite, Dorothy (1953). *British Journal of Industrial Medicine*, **10**, 27.
Heymann, B., and Freudenberg, K. (1925). *Morbidität und Mortalität der Bergleute im Ruhrgebiet*. Baedeker, Essen.
Holčík, L. J. (1952). *Lék. Listy*, **7**, 174.
Knowles, R. B. (1944). *Brit. med. J.*, **2**, 430.
Kuborn, Hyacinthe (1863). *Étude sur les maladies particulières aux ouvriers mineurs employés aux exploitations houillères en Belgique*. Delahaye, Paris.
MacCormac, H. (1937). *Brit. J. Derm.*, **49**, 409.
Nils, T., and Skog, E. (1953). *Acta derm.-venereol.*, **33**, 466.
Ramazzini, B. (1746). *A Treatise on the Diseases of Tradesmen*. London.
Rosen, G. (1943). *The History of Miners' Diseases*. Schuman's, New York.
Schwartz, L., Tulipan, L., and Peck, S. M. (1947). *Occupational Diseases of the Skin*, 2nd ed. Lea & Febiger, Philadelphia.
Sneddon, I. B. (1951). *Trans. Ass. industr. med. Offrs*, **1**, 142.
Squire, J. R., Cruickshank, C. N. D., and Topley, E. (1950). *Brit. med. Bull.*, **7**, 28.
Thackrah, C. T. (1832). *The Effects of Arts, Trades, and Professions, and of Civic States and Habits of Living, on Health and Longevity*, 2nd ed. Rees, Orme, Brown, Green and Longman, London.
White, R. Prosser (1915). *Occupational Affections of the Skin*. Lewis, London.
Wiesel, C., and Arny, M. (1952). *Amer. J. Psychiat.*, **108**, 617.

MISCELLANEA

Occupational Mortality

Coronary Heart Disease in 1950 with Some Related Observations

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To start with a thoroughly subjective, qualitative, untestable, and altogether unscientific statement, the Registrar-General's *Decennial Supplements* (concerned with occupational mortality) are the most important documents for social medicine that appear anywhere! We therefore owe a particular debt of gratitude to the General Register Office that an interim report on the massive analysis now being made of the mortality in 1949-53 (the five years round the census of 1951) has been published in the form of a series of tables for the single year 1950 (Registrar-General, 1954b). No occupational mortality data have been published since the volume referring to the years 1930-32 (Registrar-General, 1938) because no census was held in 1941, and without the numbers at risk supplied by the census the mortality of men in different occupations cannot be measured. The year 1951 is the centenary of occupational mortality studies by the General Register Office.

There is much of interest on coronary heart disease in the 1950 report. This condition may be said to have " arrived " in the last 20 years, emerging from obscurity in the 1920s to be reported increasingly commonly as a cause of death during the inter-war period (Morris, 1951; Registrar-General, 1929-1955). Although one year's data may not provide entirely reliable figures on some questions (having regard especially to the sample basis of the populations at risk) (Registrar-General, 1952), none at all on many others, and the full five years' analysis may produce some rather different pictures, the observations in the 1950 volumes are certainly worth noting. The present occasion will also be taken (since this is a " miscellany ") to refer in rather random manner to some other matters on the margins of industrial medicine that may be of interest to readers.

Social Class—New Diseases for Old

Once again we are provided with tables of mortality in the five social classes which have been built up from the thousands of individual occupations. The analysis (Table 1) for males shows that Class I had about 50% more mortality from coronary heart disease than the average, and almost twice as high a death rate as Class IV. Class V, on the other hand, did slightly worse than Class IV, which is possibly due to the drift of men on account of ill-health into unskilled, Class V " light " jobs reserved officially or unofficially for disabled persons (night-watchmen, lift attendants, etc.). This excess of mortality in the upper classes occurs of course in several other conditions. In general, it is one of the characteristics of our changing health problems that the " new " diseases show less of the concentration among social Classes IV and V that was so pronounced in the older public health problems. Fig. 1 is an attempt to illustrate this. In its upper half are four typical " classical " diseases: three show a marked " poverty trend ". Contrariwise, in the lower half of the figure, of the four selected conditions which are (or appear to be) more common than in the past, only cancer of the bronchus shows this type of class trend, and it is small compared with that in bronchitis. Moreover, in such of the " old " diseases as did show a higher mortality in the upper social classes, the gap between the classes seems to be tending now to narrow (Morris and Heady, 1955).

Sex Differences

Table 1 shows that in 1950 the class gradient of mortality among married women was opposite to that in males. In view of the very different clinical picture of this disease in men and women (the condition, for example, is relatively far less common in women before the menopause*, is probably less severe in women, and has special associations in women with hypertension and diabetes) this contrast in epidemiological behaviour, the *social* picture of the disease, is interesting, and it is not the only instance.

MORTALITY AT AGES 45-64 PER 100,000
ENGLAND AND WALES
1950-52

	Conurbations	Rural Districts	Urban Excess
Males	286	211	35%
Females	70	68	3%

*Because of current interest in hormonal factors in atherosclerosis (Friedberg, 1949; Katz and Stamler, 1953) it may be said straight away that it is unlikely that these are responsible in any simple fashion for this social class trend in women. As might be expected, at 25 to 44 or 49 years of age, which may be conveniently regarded as " pre-menopausal ", married women who have borne a child have a lower mortality, about a third lower, from coronary heart disease than married women who have not, and these in turn, have a substantially lower mortality than other women (Registrar-General, 1954a). However, fertility is greater in the lower social classes than in the upper. (Simplifying the data of the " *Family Census* ", for example (Glass and Grebenik, 1954), labourers' wives had on average 3·4-4·5 children, manual wage-earners' wives, 2·7-4·0; and their fertility was higher than that of the wives of non-manual workers, with two to three children. The lowest fertility group were the wives of salaried employees and professional workers with on average 1·7 to 2·4 children, approximately.) Therefore the coronary death rate for women might be expected to be lower in Social Class V than in Social Classes III, II, and I if fertility was the predominant factor in producing the trend of mortality, instead of which, in 1950, Social Class V recorded a higher mortality from coronary heart disease than these other classes.

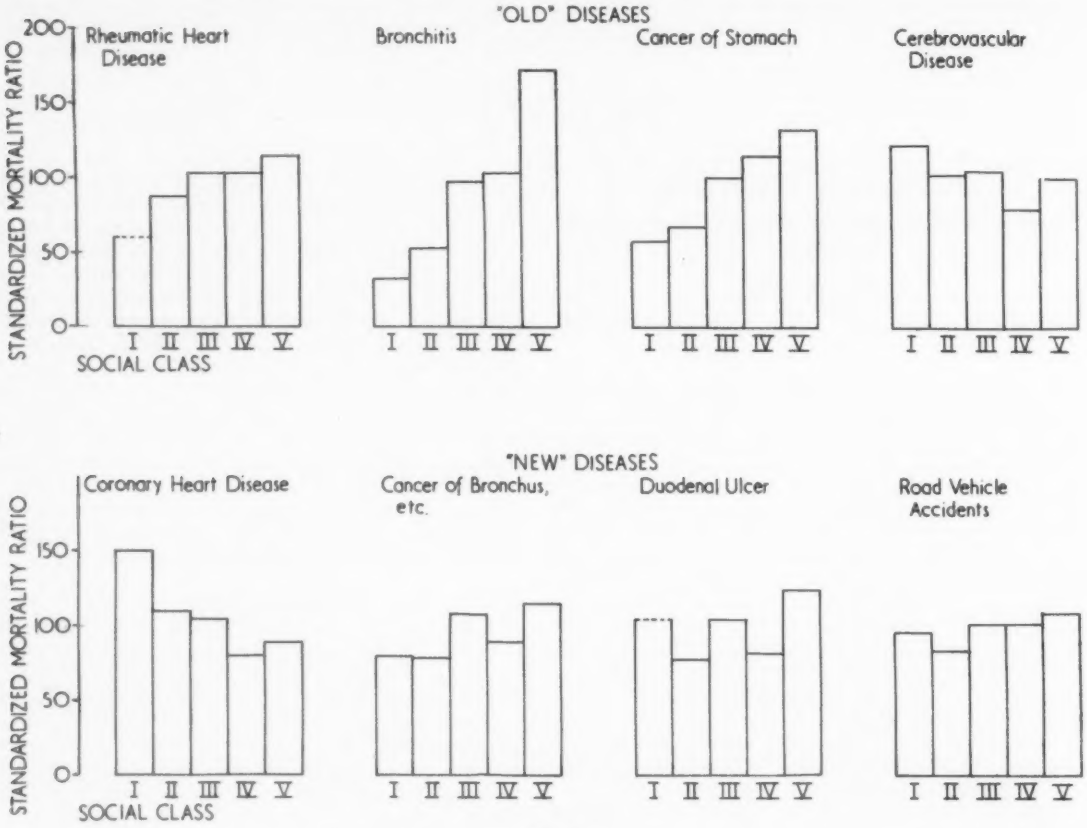

FIG. 1.

TABLE 1

MORTALITY FROM CORONARY HEART DISEASE IN THE DIFFERENT SOCIAL CLASSES, ENGLAND AND WALES, 1950, AT AGES 20-64 INCLUSIVE*

Social Class	Description	Standardized Mortality Ratios	
		Males	Married Women
I	Major professions, etc.	150	92
II	Smaller businesses and other professions, etc.	110	93
III	Skilled workers, blackcoated, etc.	104	101
IV	Semi-skilled and agriculture	79	100
V	Unskilled; most labourers	89	108
All		100	100

* Registrar-General (1954b).

Occupation

The 1950 Supplement provides death rates by major causes for a limited number of occupations. Fig. 2 shows a range from Class I, mostly professional men, with an S.M.R. of 150, through the national average of 100, and down to 57 among builders' labourers. What can be learnt from such a distribution ? The data are too slight to base hypotheses upon them, but they may be useful in considering hypotheses derived from other sources.

Facts and Fancies about Coronary Heart Disease

Several environmental factors, ways of life, are now postulated to affect the occurrence of coronary heart disease, or its natural history.* To summarize very arbitrarily, these are:—

(1) Diet (hypothesis: high fat intake, and particularly of animal fat, is harmful; more recently, a deficiency of essential fatty acids is harmful).

(2) Habitual physical activity (hypothesis: this is protective).

(3) Cigarette smoking (hypothesis: this is harmful).

(4) Alcohol (hypothesis: this is protective).

(5) Nervous strain (hypothesis: this is harmful).

(6) Obesity, *i.e.*, overeating available food (hypothesis: this is harmful).

* (Bronte-Stewart, Keys, and Brock, 1955; Bronte-Stewart, Antonis, Eales, and Brock, 1956; Friedberg, 1949; Hammond and Horn, 1954; Katz and Stamler, 1953; Morris, 1951, 1955; Morris, Heady, Raffle, Roberts, and Parks, 1953).

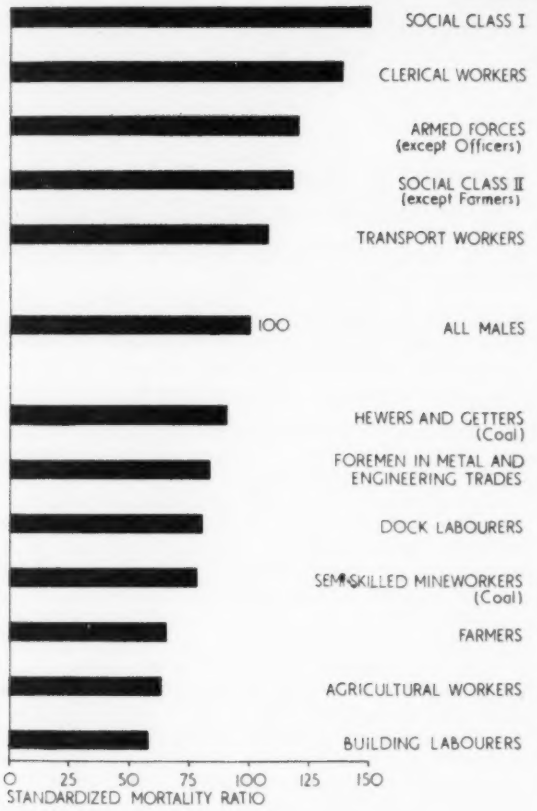

FIG. 2.

It is, or ought to be, an interesting exercise to consider the occupations listed in Fig. 2 in terms of these six possible factors.

The first thing that strikes me in relation to the super-nutrition hypothesis is the low ratio of farmers and agricultural workers when the probably favourable situation of this group compared with the others during the period 1940-1950 is remembered. For miners and clerks, we have details of the model, albeit small, enquiry conducted recently in Scotland (Garry, Passmore, Warnock, and Durnin, 1955) and these are summarized in Table 2. If calories derived from fat are the crucial factor, this study lends no support to the suggestion that dietary differences among occupation groups might be producing their different mortality rates from coronary heart disease.

The physical activity hypothesis breaks about even in these ratios. For example, the S.M.R. for clerks of Social Class III is expectedly high (quite a bit higher than of Social Class II), for hewers and getters it is unexpectedly high. One of the difficulties in testing this hypothesis is the fewness of skilled heavy workers nowadays, and we shall have to wait for the full 1949-53 tabulations before a proper analysis can be made. Nothing is known about characteristic physical activity (if any) in leisure for any type of occupation.

Very little can be said about smoking habits in different occupations. Coal-miners may not smoke as much as others (Thomas, Cotes, and Higgins, 1956). Perhaps this is also true of agricultural workers. Even less is certain about habits of alcohol consumption. We all have ideas about nervous strain, responsibility, the stresses on brain-workers, etc., but they are not supported by any facts. The figures in Table 3 may be relevant; they show little correlation between school-leaving age, which is some indication of educational levels, and mortality rates from coronary heart disease. There is nothing useful to be said so far as I know about the prevalence of obesity among men in different occupations.

TABLE 3

CORONARY HEART DISEASE AND EDUCATION LEVELS

Occupation	Standardized Mortality Ratios Coronary Heart Disease* (1950)	Proportion Leaving School at 15 Years of Age or Later† (1951 Census)
Professional, Social Class I	150	83%
Clerical workers	138	48%
Armed Forces (except officers)	120	35%
Social Class II (except farmers)	118	50%
Transport workers	107	9%
All males	100	24%
Hewers and getters (coal)	90	4%
Foremen in metal and engineering trades	88	15%
Dock labourers	80	40%
Semi-skilled mineworkers (coal)	78	7%
Farmers	65	24%
Agricultural workers	63	17%
Building labourers	57	7%

* Males, aged 20-64 years inclusive in England and Wales (Registrar-General, 1954a).

† Males, aged 15 and over in Great Britain (Registrar-General, 1952).

Work to be Done

I am intentionally closing on this negative note. It is quite clear that if we are to study the relations of occupation to diseases like "coronary thrombosis"

TABLE 2

NUTRITION OF MINERS AND CLERKS*

Occupation	Energy Expenditure				Food Intake		
	Total Calories Expended	At Work	In Leisure and Other Activities	In Sleep, etc.	Total Calories Consumed	As Fats, (g.)	Calories from Fats (% of Total Calories)
Miners	3,660	1,750	1,420	490	4,030	150	33·5
Clerks	2,800	890	1,410	500	3,040	119	35·3

*Nineteen miners and 10 clerks studied over a seven-day period (Garry, Passmore, Warnock, and Durnin, 1955).

which are not simple occupational hazards, it will be necessary to know not only about the direct connexions between occupations and the particular disease, but also about the connexions between work and the other putative factors which are currently being studied. In the present instance, this involves, first, the connexions between occupation and various relevant habits of living. Thus, there is every reason to suppose that obesity is not equally distributed amongst various occupations; it is a reasonable proposition that men in different jobs have different smoking and, possibly, food habits; and that they enjoy leisure activities of different kinds. There are wide fields here on the margins of industrial medicine waiting to be tilled; and the situation today is rich with opportunity for the student who wishes to learn something about the causes of health and ill-health in middle age.

I am grateful to my colleagues in the Social Medicine Research Unit for their help.

REFERENCES

Bronte-Stewart, B., Keys, A., and Brock, J. F. (1955). *Lancet*, **2**, 1103.
——, Antonis, A., Eales, L., and Brock, J. F. (1956). *Ibid.*, **1**, 521.
Friedberg, C. K. (1949). *Diseases of the Heart*, Saunders, Philadelphia.
Garry, R. C., Passmore, R., Warnock, G. M., and Durnin, J. V. G. A. (1955). *Spec. Rep. Ser. med. Res. Coun. (Lond.)*, No. 289.
Glass, D. V., and Grebenik, E. (1954). *The Trend and Pattern of Fertility in Great Britain.* A Report on the Family Census of 1946. Parts I and II. H.M.S.O., London.
Hammond, E. C., and Horn, D. (1954). *J. Amer. med. Ass.*, **155**, 1316.
Katz, L. N., and Stamler, J. (1953). *Experimental Atherosclerosis.* (Amer. Lect. Ser. No. 124.) Thomas, Springfield, Illinois.
Morris, J. N. (1951). *Lancet*, **1**, 69.
——, (1955). *Med. Offr.*, **94**, 251.
——, and Heady, J. A. (1955). *Lancet*, **1**, 554.
——, ——, Raffle, P. A. B., Roberts, C. G., and Parks, J. W. (1953). *Ibid.*, **2**, 1053, 1111.
Registrar-General (1929-1955). Statistical Review of England and Wales. Part I, Tables, Medical, 1928-1954. H.M.S.O., London.
—— (1938). Decennial Supplement, England and Wales, 1931. Part IIA, Occupational Mortality, 1930-32. H.M.S.O., London.
—— (1952). Census 1951, Great Britain. One per cent. Sample Tables. Parts I and II. H.M.S.O., London.
—— (1954a). Statistical Review of England and Wales, 1946-50. Text, Civil. H.M.S.O., London.
—— (1954b). Decennial Supplement, England and Wales, 1951. Occupational Mortality. Part I. H.M.S.O., London.
Thomas, A. J., Cotes, J. E., and Higgins, I. T. T. (1956). *Lancet*, **1**, 414.

Exposure to Trichloro-ethylene during an Industrial Degreasing Operation

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(RECEIVED FOR PUBLICATION JUNE 11, 1956)

The effect of trichloro-ethylene vapour upon workers exposed to it has been the subject of several detailed studies in recent years (Ahlmark and Forssman, 1951; Frant and Westendorp, 1950; Grandjean, Münchinger, Turrian, Haas, Knoepfel, and Rosenmund, 1955). We are reporting the results of a routine industrial hygiene survey in order to emphasize the importance of such surveys in detecting undesirable contamination of the workshop air.

Description of the Process

The degreasing plant concerned consisted of a single gas-heated tank, approximately 2 ft. 6 in. × 3 ft. 6 in., and divided laterally to provide liquid and vapour phase degreasing sections. The work to be cleaned was mainly small machined components, which were packed into wire baskets fitted with long handles, and then placed in the tank. In some cases where the baskets were tightly packed with very small components, such as nuts and bolts, manual agitation in the liquid degreaser was necessary in order to facilitate the penetration of the solvent. The volume of the regular output from the machine shop involved a considerable quantity of degreasing, and the degreaser unit was heavily loaded.

Covers were not provided on the tank, but vapour-cooling coils were fitted near the upper edges of the tank. Two propeller fans in the outer wall of the shop extracted air at high level, and a further fan extracted air via a draining grid fitted in the floor of the shop near to the tank. The general layout is shown in Fig. 1. Three men were involved in the operation of the plant.

Air Sampling and Analysis

Air sampling was carried out on a day when the normal volume of work was being handled. Air was drawn through two U-tubes in series, each limb containing approximately 5 g. of dried 20- to 60-mesh silica gel. The rate of flow was controlled at approximately 1 litre per minute by the insertion of a critical orifice in the suction line between the U-tubes and the vacuum pump. Analysis of the air samples was carried out by the method described by Elkins (1950), the final titration being performed in a blackened box illuminated by a photographic darkroom lamp with an Ilford yellow safelight No. VS901.

The efficiency of collection and recovery had previously been checked in the laboratory at a concentration of 100 p.p.m. Using stock gel, two U-tubes in series gave recoveries of 65·9 p.p.m. and 27·4 p.p.m respectively, whereas overnight drying of the gel at 105 to 110° C. improved the recoveries to 90·7 p.p.m. and 3·6 p.p.m. Drying of the gel is thus advisable if a single U-tube is to be used for collection.

The air samples were collected simultaneously at breathing level at three positions in the workshop, indicated as A, B, and C in Fig. 1. Positions A and B were selected as corresponding as closely as practicable to the main working positions D and E. Position C was representative of the general conditions in the shop away from the immediate vicinity of the tank. Samples were taken for two periods, one of 50 minutes and one of 53 minutes; less work was handled during the second period owing to the approach of the lunch break. The results of the air analyses are shown in Table 1.

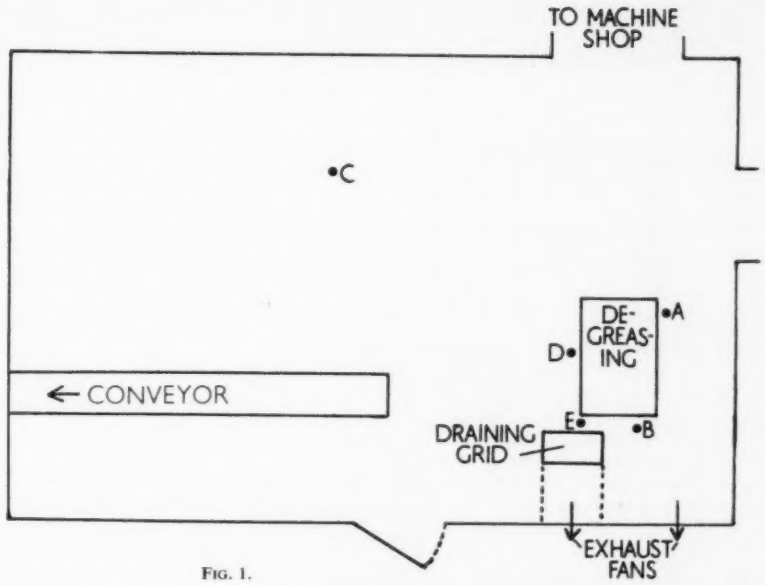

FIG. 1.

TABLE 1

CONCENTRATIONS OF TRICHLORO-ETHYLENE IN AIR OF WORKSHOP

Sample No.	Position	Concentration (p.p.m.)
1	A	637
2	B	423
3	C	73
4	A	494
5	B	372
6	C	62

Urine Sampling and Analysis

The absorption of trichloro-ethylene vapour is indicated by the presence in the urine of trichloro-acetic acid. Urine samples were obtained from each of the three operatives engaged on the degreasing process for a period of 24 hours from noon on the day on which the air samples were collected, and analysed by the method described by Powell (1945). The results are shown in Table 2. A spot urine sample obtained from a laboratory technician who had not been exposed to trichloro-ethylene vapour when analysed by the same procedure indicated an excretion of only 2·5 mg. per litre.

TABLE 2

ANALYSIS OF URINE SAMPLES FOR TRICHLORO-ACETIC ACID

Sample	24-Hour Excretion	
	Total (mg.)	(mg./litre)
Res.	264	175
Bid.	255	204
Rig.	416	258

Maximum Allowable Concentrations

Air Concentrations.—Divergence of opinion exists regarding the maximum allowable concentration of trichloro-ethylene vapour. On the basis of exposure for 40 hours a week, I.C.I. Ltd. recommend 400 p.p.m. The American Conference of Governmental Industrial Hygienists recommends 200 p.p.m. for a similar length of exposure, although for some time previously it gave the figure of 100 p.p.m., while Elkins (1950) suggests 150 p.p.m. More recently Grandjean *et al.* (1955) postulated that the maximum allowable concentration should not exceed 40 p.p.m. for continuous exposure for eight hours a day, and they quote a Russian value of 9 p.p.m.

The operatives in this case were exposed for 45 to 50 hours a week; the concentrations measured near to the tank exceeded the highest maximum allowable concentration quoted above when corrected approximately for the increased exposure time. The senior operative (Bid.) spent a considerable portion of his time in very close proximity to the tank, and the other two operatives were engaged in the movement of material to and from the region of the tank.

Urinary Concentrations of Trichloro-acetic Acid.—Ahlmark and Forssman (1951) found symptoms of exposure to trichloro-ethylene in about half of persons who excreted 40 to 75 mg. of trichloro-acetic acid per litre of urine, and in almost all those who excreted 100 mg. per litre or more. With exposures which caused regular excretion of 200 mg. per litre or more, symptoms were often so pronounced as to cause absence through sickness.

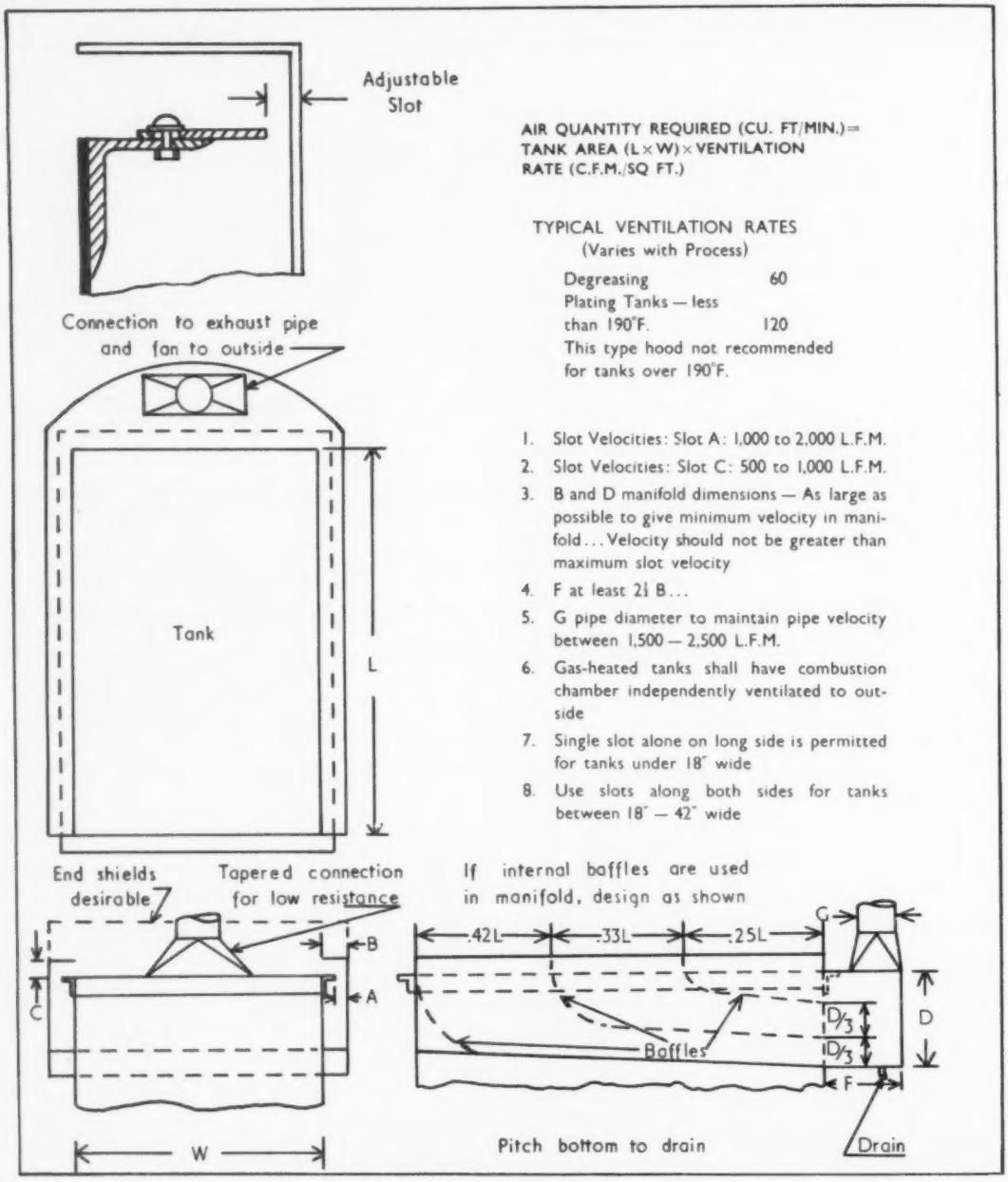
Adjustable Slot
AIR QUANTITY REQUIRED (CU. FT/MIN.)= TANK AREA (L×W)×VENTILATION RATE (C.F.M./SQ FT.)
TYPICAL VENTILATION RATES
(Varies with Process)
Degreasing 60
Plating Tanks — less than 190°F. 120
This type hood not recommended for tanks over 190°F.
Connection to exhaust pipe and fan to outside
Tank
L
1. Slot Velocities: Slot A: 1,000 to 2,000 L.F.M.
2. Slot Velocities: Slot C: 500 to 1,000 L.F.M.
3. B and D manifold dimensions — As large as possible to give minimum velocity in manifold... Velocity should not be greater than maximum slot velocity
4. F at least 2½ B...
5. G pipe diameter to maintain pipe velocity between 1,500 — 2,500 L.F.M.
6. Gas-heated tanks shall have combustion chamber independently ventilated to outside
7. Single slot alone on long side is permitted for tanks under 18" wide
8. Use slots along both sides for tanks between 18" — 42" wide
End shields desirable
Tapered connection for low resistance
If internal baffles are used in manifold, design as shown
B
A
C
W
.42L
.33L
.25L
G
D/3
D/3
D
Baffles
F
Pitch bottom to drain
Drain

FIG. 2.—Drawing of the lateral hood for open tanks.

On the basis of these findings Ahlmark and Forssman suggested that a concentration of 20 mg. per litre of urine should be the upper limit allowed. Frant and Westendorp (1950), however, found little correlation between urinary concentrations and complaints from workers.

Grandjean *et al.* (1955) considered that determinations of trichloro-acetic acid in urine are an insufficient index, and that they should be accompanied by air analyses. They recommended a double standard, namely that the concentration of trichloro-ethylene in air should be kept below 40 p.p.m., and that the concentration of trichloro-acetic acid in urine should be less than 96 mg. per litre.

Clinical Examinations

The three employees seen in this investigation were aged 32, 30, and 37; one (Bid.) had been exposed to trichloro-ethylene for 10 years, and the other two for nine months. All three reported vague symptoms of fatigue, headaches, and dryness of the lips and mouth. Two were subject to periods of loss of appetite and of flatulence, and the operator with the longest exposure stated that he was subject to occasional feelings of vertigo. No organic defects were discovered on clinical examination. The haemoglobin values (determined by the cyan-haematin method) were somewhat low (Bid. 84%, Res. 89%, Rig. 89%); no abnormality was found in red or white cell count, differential white count, and packed cell volume.

Discussion

This study is presented to emphasize that unless adequate precautions are taken during industrial degreasing operations there may be considerable contamination of the air by trichloro-ethylene.

The primary cause of the high concentrations recorded appeared to be the use of a tank which was too small for the volume of work handled. This resulted in two major operating errors. First, not enough time was allowed for the draining of liquid trichloro-ethylene from the material before withdrawal from the tank, so that quantities of liquid solvent were withdrawn; but for the presence of the draining grid, even higher concentrations would have occurred. Secondly, the rapid removal of material induced a surge of vapour, which at times was almost overpowering to an observer standing near the tank. It will be noticed from Fig. 1 that the exhaust fans extract such vapour across the breathing zone of a worker at position E. The use of a mechanical hoist, limiting speed of withdrawal to 11 feet per minute or less, is strongly to be recommended (Horowitz, 1955).

When properly designed and efficiently operated, degreasers may often be used quite safely without exhaust ventilation. In circumstances where exhaust ventilation is necessary, the most efficient method of application is by means of lateral slots placed along the edges of the tank. Fig. 2 shows a typical design for such a slot exhaust system. To prevent excessive vapour loss through the exhaust system, there must be adequate free-board between the vapour line and the slots. Experience suggests that excessive loss of solvent when it occurs is due mainly to the carry-out of liquid on improperly racked work, and not to ventilation.

We are indebted to the management of the factory and the workers concerned for their ready cooperation, and to Professor G. P. Crowden and Dr. P. J. R. Challen for helpful criticism and advice.

Fig. 2 is reproduced by permission of the Division of Industrial Hygiene, New York Department of Labor.

References

Ahlmark, A., and Forssman, S. (1951). *Arch. industr. Hyg.*, **3**, 386.
Elkins, H. B. (1950). *The Chemistry of Industrial Toxicology*. Wiley, New York.
Frant, R., and Westendorp, J. (1950). *Arch. industr. Hyg.*, **1**, 308.
Grandjean, E., Münchinger, R., Turrian, V., Haas, P. A., Knoepfel, H.-K., and Rosenmund, H. (1955). *British Journal of Industrial Medicine*, **12**, 131.
Horowitz, L. D. (1955). New York State Department of Labor, Division of Industrial Hygiene, Monthly Review, **34**, 9.
Powell, J. F. (1945). *British Journal of Industrial Medicine*, **2**, 142.

The British Occupational Hygiene Society

The first provincial meeting of the Society was held at University Hall, Liverpool, in April, 1956. During the afternoon of April 19 three papers were read by members of the staff of the General Chemicals Division, Imperial Chemical Industries Ltd.; they dealt respectively with chlorine, dust sampling and analysis, and fluorine. A film illustrating the work of the General Chemicals Division was also shown. The new President of the Society, Dr. C. G. Warner, presided over the meeting and delivered an address after dinner that evening.

On the next day members were entertained by the General Chemicals Division of Imperial Chemical Industries and conducted round the Castner-Kellner and Rocksavage works.

Presidential Address: The Pneumoconiosis Problem in Coal-mines

C. G. WARNER

Divisional Dust Suppression Scientist, National Coal Board, South Western Division

The Society is now starting its fourth year of existence, but during our brief life we have indeed achieved considerable measures of success in many directions. The reports of the conferences of the Society make interesting reading. At the inaugural meeting of the Society the then Minister of Labour and National Service, Sir Walter Monckton, in his opening address remarked:

> "The prominence now being given in Government and other quarters to the development of provision for occupational health in its widest sense shows that occupational hygiene is a subject which will receive increasing attention.
>
> "It is particularly opportune that the foundation of this Society should come at a time when efforts are being made to establish and develop this important service to industry. The application of knowledge of practice of many kinds is necessary to achieve these objects. The medical profession, physiologist and the psychologist must work hand in hand with the engineer, the chemist and the physicist and a vital factor must be the closest collaboration between industrial research and industrial health research."

Sir Walter continued:

> "During the last decade there has been a marked increase in the interest shown in health matters by industry. But it cannot be said that the facilities for studying occupational risks to health have kept pace with the growing awareness of the importance of this subject. This Society is following this principle and I am glad to say that its membership is not limited to scientists, but includes others with interests and responsibilities in the wide field of occupational health."

Dr. Bedford, the first President of the Society, to whom is due much of the credit for its inception and constitution, reinforced Sir Walter Monckton's comments by referring to the importance of team work. Dr. Bedford, in fact, put it in these words:

> "Occupational hygiene requires the employment of many skills embracing those of the various branches of medical sciences, the physical sciences, and engineering. Its research problems call for the work of highly-skilled chemists, physicists, petrologists, engineers, physiologists, and psychologists as well as that of physicians and pathologists. Most of these need to acquire either the skill, or to evoke the help, of the statistician."

In both research and its application, occupational hygiene calls for team work—it is a joint field of specialization.

Only last April, Dr. Rogan in his presidential remarks commented on the solidarity of our Society. Although it was not then three years old, its record of progress is eminently satisfactory. Its membership is increasing, its finances are healthy, and it is represented by Dr. Bedford on the Committee instituted by Sir Walter Monckton under the title of the Industrial Health Advisory Committee.

The terms of reference of our Society, which briefly are to promote the science of occupational hygiene, seem to be bearing fruit by the practical activities that our body has been able to carry on during its brief life.

The Pneumoconiosis Problem

I feel that sufficient has been said on the general policy behind the fields of work we cover in our daily activities. I wondered, though, whether it would be of interest to the members to describe briefly the practical results which have taken place in recent years in one of our major industries. I refer to the problem of pneumoconiosis as occurring particularly in the coal-mining industry.

Work on this important subject has been going on for a number of years and when scanning through our list of membership I was very impressed to note the considerable number of our members who have contributed, or are contributing, to the subject I have named. Starting with our roll of presidents, without exception all who have taken the chair so far have been, or still are, actively engaged in the researches relevant to the air-borne dust hazard from mining. Dr. Bedford, Professor King, and Dr. Rogan are names which come to mind immediately in any discussion on the subject. Also, in that respect I may claim that I am not unconnected with the problem myself.

Among the pioneer workers in this field, the name of Dr. Amor, whom we are happy to see here with us tonight, has an important place on the roll of fame. His pioneer work into the problem of silicosis is a classic contribution to the subject. Official bodies represented actively in our membership, namely the Medical Research Council, the Safety in Mines Research Establishment, the Pneumoconiosis Research Unit of the Medical Research Council, and the National Coal Board, all have been, and still are, working in this important field.

The problem has been tackled on the broad lines of policy defined earlier, namely as a team job. In the wide-scale work which has taken place all the aspects have been represented and the collaboration between medical, scientific, and engineering branches has been very evident.

It was apparent many years ago that at least in South Wales a hazard was prevailing. Much pioneer work had been carried out in various parts of the British coalfield in the early years of this century, but it was not until the 1930s that the full impact of the problem became evident. Ultimately, in 1936, the Medical Research Council was asked to carry out the first large-scale investigation in South Wales. This was a team job and some 22 investigators covered the medical, pathological, and environmental phases of the work. From that work certain conclusions were drawn. The incidence of lung trouble was for the first time coordinated and degrees of certification put on a more rational basis. Also, there appeared to be a relation between quantity of disease and the quantity of air-borne dust that men inhaled. In that respect Dr. Bedford and myself must take our share of blame or credit for putting forward targets of dustiness for working conditions, and the figures we suggested have been the framework in the outlook as it prevails at the present time under the aegis of the Approved Conditions Scheme. At the time of our original investigation the air-borne dust concentrations which we were measuring were considerably in excess of our suggested safety figures. We had no idea how the mining engineer could achieve what we were then proposing. Even in South Wales, the focal point of the industrial hazard, there was little practical approach—I refer now to the period 1937 to 1941—to active dust suppression measures during routine mining operations. In 1942 the principle of water infusion was developed in South Wales and this method of combating the dust proved to be one of the main methods by which the engineer could reduce the make of dust. The use of this classic method of dust suppression rapidly expanded in South Wales and in practice proved to be one of the chief answers to the doctor's prayer. By this method, allied to other quickly developing suppressive measures, it was found that the engineer could achieve the very strict target levels which Dr. Bedford and I had indicated.

This chain of events, which showed that theoretical requirements could be achieved practically, was a most fortunate one and from that time the impact of preventive work against the health hazard from air-borne dust has gained increasing momentum, first in South Wales and, subsequently, through the other coalfields of the nationalized industry.

The improved position which I have indicated in the foregoing remarks did not happen as quickly as they might imply. Through the ensuing years it was an uphill fight, a fight in which the engineer was taking the brunt of the burden. It was his responsibility to achieve success and the medical investigators could only await any resultant effects of improved conditions on the health of the worker.

The uphill fight was a practical one and I took part in that fight. Having proposed, in conjunction with Dr. Bedford, these extremely difficult targets of dustlessness, I had the temerity to join the industry in South Wales in the anthracite field in an endeavour to put them into practice. Too truly was I asked to take our own medicine. However, the process turned out to be most interesting and from the period 1943 to 1947, when nationalization took place in the anthracite region, we did make considerable strides to improve working

conditions for the miner. The results of the practical work, of course, did not register in the medical statistics immediately and it is one of the difficulties of the whole of this field of work to relate inherently or directly the effect of dust, *per se*, on the incidence of disease. Time is showing, without doubt, that there is a broad linkage between these two factors, although the reaction period shows an apparent delay of some years.

In the pioneer work in the anthracite mines the practical application of all known suppressive measures went on apace and the reduction in air-borne concentrations through the period of years was most impressive. Quite steadily conditions were being brought down to the target levels specified and the fact that this practical hygiene result had been brought about was most comforting to all concerned in the campaign. Once again the results of team work were being illustrated and particular credit was due to the mining engineers and the colliery personnel at all levels. All cooperated to apply the knowledge made available by the research workers.

Meanwhile, in other directions the research workers I referred to in my earlier remarks were continuing their own specialized contributions to the general problem, and the many points of interest from the clinical, pathological, chemical, and other scientific studies of the dust hazard continued to receive full attention.

Nationalization of the industry only served to give impetus to the necessity of coping with the industrial problem, and in the very early days of the constitution of the National Coal Board this body stated as one of its points of policy that air-borne dust was to be considered as dangerous wherever and whenever it occurred.

Later, in 1952, the Pneumoconiosis Field Research scheme was undertaken by the National Coal Board. Twenty-five collieries were selected throughout the country and they were to be the subject of investigation for a period of at least 10 years.

All personnel employed at the collieries, above and below ground, were to be examined regularly both clinically and radiologically. Working histories of all individuals would be built up and would include details of the air-borne dust concentrations, temperature and ventilation conditions, etc., of the working environments. In this way the relation between dust and disease would be firmly established. The existing targets of permissible dustiness could be checked and safe standards of air-borne dust concentrations in British coal-mines established for all time.

The research scheme is the biggest project in practical industrial hygiene yet envisaged in the world and we hope in the near future to receive a paper by Dr. Fay, who is in charge of the environmental studies, describing the logistics of this aspect of the work.

Incidence of Pneumoconiosis.—The different levels of incidence of the disease which have prevailed between the various coalfields in Great Britain have been a source of perplexity and that position prevails to the present time.

Wales originally was the black spot and a severe rate of incidence appeared to be localized to that coalfield. But, one wonders whether incidence is not also a function of awareness of the disease. Certainly in Wales people are dust conscious and have been for many, many years. This awareness of the disease may have tended to disclose it earlier in that location, although it may yet be that the idea that there is something particularly pernicious about South Wales dust may prove to be true. It must be realized, however, that today the bulk of the numbers certified in Wales show only an early stage of dust retention and their certification at the first levels of recognized pneumoconiosis does not mean that the individuals are necessarily severely incapacitated. Far from it, they only bring to the fore the very important requirement for good industrial hygiene. Prevention is the slogan in this dust campaign and, quite rightly, the industry is now assuring itself that not only will patients with the first signs of dust retention be prevented from progressing, but also that people with a clean bill of health are exposed to only the barest risk of developing any trouble themselves.

The fight against dust has been going on longest in South Wales and we can, accordingly, from data available from that coalfield, perhaps note any potential relation between dust and disease.

Following the change in legislation in 1943, which extended the range of compensation for pneumoconiosis, the rate of certification per 1,000 men employed in divisions other than South Wales rose from 0·3 in 1943 to 1·9 in 1947, while the rate for the last complete year available, namely 1954, was 5·8. In the South Western Division certification rates per 1,000 men employed, after rising to a peak of 55·6 in 1945, dropped to 30·8 in 1947. Since then the falling trend in the South Western Division has been maintained and in 1954 the rate was 9·2 per thousand men employed.

Between the South Western Division and the rest of the country we have, therefore, the diametric comparison of a falling trend in South Wales and a rising one in the rest of the country, and this comparison has persisted for a number of years.

It would be premature to draw any conclusions from these figures about the real incidence of pneumoconiosis and, except perhaps in the South Western Division, it is too early to estimate with any confidence the effectiveness of dust suppression measures. There are many factors, apart from real incidence, which affect the number of certifications—rates and conditions of compensation, standards of certification, ease of obtaining alternative employment, and awareness of the pneumoconiosis hazard. But, even if the certification and real incidence rates were identical, the figures of certifications would not at present be a measure of the effects of dust suppression.

Pneumoconiosis is a chronic disease, few cases developing in less than five to 10 years, but many taking 20 to 30 or more years to develop, so that remedial measures take a long time to show results.

In the South Western Division the rapid rise in certifications between 1943 and 1945 can be accounted for by the change in legislation in 1943, leading to a rush of applications for certification. This rush could not all be dealt with by the available medical staffs until additional doctors were appointed in 1944-45. The rush

over, there has been a steady decline in the number of new certifications in the South Western Division after 1945. It is just possible that the dust suppression measures actively started in 1942 have begun to take effect. It is to be expected that anti-dust measures will be quicker to show results in the South Western Division than elsewhere.

In other divisions where the consciousness of danger from pneumoconiosis and of the procedure for obtaining compensation are in varying degrees less general than in South Wales, mineworkers have probably been slower in taking advantage of the extended field of compensation. This could account for the steady rise in certifications in other divisions without indicating any rise in the real incidence of pneumoconiosis.

Although the efficacy of dust suppression is at best only beginning to become apparent in the South Western Division, there is nothing in the figures under review to shake our faith in dust suppression as the true remedy. Moreover, despite the fact that the certification rate does not represent the real incidence of pneumoconiosis, it is sometimes the only available pointer to the areas that most urgently need attention.

During the period under review, working conditions in the pits in South Wales have altered out of all knowledge and we can say the levels of air-borne dustiness in the pits 15 years ago were up to 10 times those prevailing at the present time.

Considering the numbers of certifications in another way, South Wales in 1942 by itself had 20 times the total number of cases from the rest of the country combined. In 1945, the peak year of certification in South Wales, when 5,224 cases of pneumoconiosis were recorded in that region, the rest of the country had 597 cases, giving a ratio of 8·8 to 1. For the last year's data available, namely 1954, the ratio is now 0·26 to 1, based on numbers of cases of 927 in South Wales and 3,542 for the rest of the country respectively. This again reflects an interesting state of affairs and so far as those of us who have been concerned in the work in South Wales feel, the pendulum is definitely swinging in the right direction. Certainly new cases are not being made in the numbers as before.

Only last week in a leading South Wales newspaper the following appeared under the heading, " Battle with Pits' Death Dust is being Won " :

> " In 20 years' time victory over the deadliest form of pneumoconiosis will be practically won in South Wales, it is forecast.
>
> " Government medical men, with the cooperation of the National Coal Board, are making vigorous efforts to abolish progressive massive fibrosis, the disease that blackens and distorts miners' lungs.
>
> " A Government doctor, who is an authority on the disease, told a *South Wales Echo* reporter that healthier working conditions in the mines, plus the declining incidence of tuberculosis, has meant a slow but steady fall in deaths from pneumoconiosis.
>
> " Most miners with the disease have simple pneumoconiosis, which is rarely fatal but which can be a contributory factor in death.
>
> " One hopes in 20 years' time we will be dealing almost entirely with simple pneumoconiosis, and that in its early stages, said the doctor.
>
> " Thirty years ago nearly all the miners who had the disease were stricken with its more deadly form, progressive massive fibrosis. It's a striking change.
>
> " An improvement in the mines largely responsible for the change is the technique of water infusion, whereby water is injected into the coal seam."

The report ended, however, on a note of anticlimax, stating:

> " But the problems of doctors never end. Now more miners complain of rheumatism."

At least that gives the research workers another hare to chase in the future.

I have not talked to you in terms of tons per man, units per ton, or presented a series of tables forming a statistical report. In this address I have tried to give a practical example which substantiates the ideals of the Society, namely that team work to promote the science of occupational hygiene is the way to resolve an industrial health problem.

Chlorine: Its Products and Uses

H. PIRIE

From the Technical Service Department, General Chemicals Division, Imperial Chemical Industries Ltd.

Since it is impossible in a brief paper to cover the entire field suggested by the above title, attention will be concentrated on liquid chlorine itself and trichloro-ethylene, one of its major products, with special reference to their safe use by customers of Imperial Chemical Industries Ltd., and the efforts made by the firm to minimize the work of factory medical officers. Reference will also be made to the scheme of the Association of British Chemical Manufacturers (A.B.C.M.) for warning labels for hazardous chemicals.

Liquid Chlorine.—Chlorine was first transported in the form of bleaching powder, invented by McIntosh at St. Rollox, and in 1890 as much as 85,000 tons was exported. Commercial development of liquid chlorine did not come until after its use as a war gas in 1915.

Chlorine is now produced by the electrolysis of brine or fused salt. A proportion is used in the producing works in the preparation of (*a*) old established inorganic derivatives, chloride of lime, chlorinated soda, muriatic acid, and (*b*) a wide and increasing range of organic products. The balance is liquefied by cold compression and packed into special steel containers. Today many tens of thousands of tons per year of liquid chlorine are transported about this country, the bulk by road and rail tank, but a substantial tonnage in drums and cylinders.

Many users have no experience in handling chemicals and safety problems arise, for example, in the case of waterworks operators or bath superintendents. To meet this obligation the following rules are observed:—

(1) Liquid chlorine must be dry and the packages and valves must be foolproof. Filling ratios must be observed and containers have to be serviced and tested regularly.

(2) The customer should know how to use the product and to handle the packages safely. His drum and tank installations require initial inspection, and instructions and precaution cards are issued.

(3) The customer should know what to do in the event of an accident. A Chlorine Emergency Service is available to deal rapidly with trouble at the premises of any user.

(4) Regular visits are made to ensure that the necessary precautions are being taken.

A similar system is in operation for all liquefied gases presenting a toxic hazard, such as phosgene and methyl chloride.

Trichloro-ethylene.—This is one of the oldest of the commercially available chlorinated organics and the one now made on the largest scale. Its essential properties are low toxicity, non-inflammability, and high solvent power for fats and waxes. It has many uses, including degreasing and dry cleaning, and trichloro-ethylene sales are a good index of industrial activity.

There is still much confusion about the physiological properties of trichloro-ethylene. It is a good anaesthetic (" trilene "), but unlike some other chlorinated hydrocarbons, it has no known chronic effects. This fact is shown by the safe working limits: trichloro-ethylene 2,100 mg./m³, carbon tetrachloride 320, chloroform 250, tetrachloro-ethane 70. Trichloro-ethylene can, therefore, be used safely provided simple precautions are taken. Chronic poisons like tetrachloro-ethane are more dangerous, since in practice it is very much more difficult to avoid repeated exposure to low concentrations of a vapour.

The attitude adopted to users of trichloro-ethylene is similar in principle to that outlined above for chlorine. We do our best to ensure that before using the product customers are fully conversant with its properties, the methods of use, and the simple precautions which should be taken. Whenever possible we ensure that similar precautions are taken by merchants or others who resell the material. Precaution cards are provided. Plants are regularly inspected by technical service representatives. An enquirer may frequently be persuaded to use a less hazardous product, such as trichloro-ethylene, in place of tetrachloro-ethane.

A.B.C.M. Labels.—The policy outlined above is designed to protect the *users* of liquid chlorine and trichloro-ethylene from the results of their lack of knowledge or carelessness. To protect the *transporters* of hazardous chemicals (railway employees, lorry drivers, storekeepers, etc.) the A.B.C.M. has devised a labelling scheme for hazardous products, which is now widely used by the chemical industry in this country. The label has been designed with four main objects in view:

(1) It should be distinctive and easily recognizable so that everyone concerned with the transport and storage of chemicals recognizes immediately that a particular package contains a potentially harmful substance.

(2) A signal word indicates the degree of hazard.

(3) The nature of the hazard is defined.

(4) The label also states the simple precautions necessary to avoid injury and what to do in cases of spillage or in cases of fire, etc.

The hazards and the precautions are given in simple standard phrases which can be understood by the layman or by fire brigade personnel. At first sight this scheme might appear to involve additional labels and additional costs, but composite labels can be evolved incorporating the actual warning label and such an integration can, in fact, reduce costs.

The A.B.C.M. scheme does not apply to liquefied gas cylinders which are already distinguished by colour markings, or to small, retail-size packs.

The scheme has been adopted by the great majority of the A.B.C.M., and the General Chemicals Division of I.C.I. Ltd. was among the first to adopt it.

There was some discussion, after Mr. Pirie's paper, on trichloro-ethylene and it was questioned whether the figure of 400 parts per million was low enough for the probable safe concentration. Ninety parts per million had been suggested in the United States and 30 in Switzerland, on account of its cumulative effect. Arrangements to secure an air current across the top of the liquid were recommended and should include both blowing and suction.

The Technique of Particle Measurement in Industrial Hygiene

G. L. FAIRS

From the Research Department, Imperial Chemical Industries Ltd., General Chemicals Division

A knowledge of the concentration and size distribution of a suspension of air-borne particles has two main applications in the field of industrial hygiene. It can be used in the general investigation of pneumoconiosis and allied diseases but it has a further and wider use in providing the data essential for the successful design of gas cleaning equipment. This latter application is assuming increased importance in view of the impending legislation embodied in the Clean Air Bill at present before Parliament.

One of the main uses of particle measurement in industrial hygiene is therefore to provide data for the design of gas cleaning plant and of equipment for the efficient collection of the particles so that they are not merely transferred from the plant atmosphere to the open air outside. Except for electrostatic precipitators all dust and mist collectors depend for their operation upon dynamic forces and these forces increase rapidly as the particle size decreases thus increasing the operating costs. It is therefore most important that an accurate assessment of the size distribution of any collection of air-borne particles should be available so that the right type of collectors can be chosen and designed to operate under the best possible conditions.

The subject of particle measurement is a very wide one and any survey of it which is to be kept within reasonable limits must of necessity be sketchy and generalized. It is hoped, however, that such a survey, while containing little which is novel for the specialists, will prove of value to those not well acquainted with the subject.

Sampling Air-borne Suspensions.—Before dealing with the question of particle measurement for this purpose, it is necessary to consider the previous operation of providing a representative sample of the suspended particles. There are a number of difficulties in this which in general increase as the size of the particles and the inertial forces acting upon them increase.

Sampling Air-borne Particles in Ducts.—If the particles are solid and are suspended in air which is passing along a duct (as for instance in a ventilation system) all that is required basically is to extract a sample from the air stream by means of a nozzle, isokinetically, that is, at a volume rate at which the linear velocity of the air in the nozzle is the same as that of the main air stream in the duct. Departures from isokinetic sampling result in under- or over-sampling the larger particles according as the nozzle velocity is above or below that in the duct. Precautions have also to be taken to ensure that the selected sampling point is not affected by disturbances such as those caused by bends or valves and if no suitable point is available it may be necessary to install a mixing baffle of the type developed by Stairmand (1951a). Such a baffle will ensure that a representative sample is obtained 3-6 pipe diameters downstream from the baffle. The extracted dust can then be collected in one of a variety of sampling devices, including miniature cyclones which can give cuts down to about 1μ for particles of density 2g/cm.^{3} (Stairmand, 1951a).

In the case of mists similar considerations apply except that a sampling cell has to be used to collect the particles. A sample of mist is drawn into the cell which is then isolated and the droplets allowed to settle into a film of immiscible liquid on a prepared cover slip which can subsequently be examined under the microscope. Care has to be taken when dealing with volatile liquids, or aqueous mists which are not at atmospheric temperature, so that the size distribution of the suspension of droplets is not altered by evaporation or condensation. This difficulty has sometimes to be overcome by the use of a modified cell (Stairmand, 1951a) which can be inserted into the fume main itself, sampling and sedimentation being carried out at the temperature of the main, the cell being subsequently flushed out with a stream of dry air at the same temperature.

Sampling Air-borne Suspensions in Stagnant Atmospheres.—When dealing with suspensions in the ordinary atmosphere of a chemical plant the problem is rather different from that of sampling suspensions in ducts since it is impossible to sample isokinetically when the velocity of the ambient air is negligible.

Under conditions, however, where the airflow is streamline and the inertial forces on the particles are negligible, the velocity of settling particles is the vector sum of their sedimentation velocity and the air velocity at that point. Walton (1954) has demonstrated that a change in air movement in a cloud of such particles set up by the introduction of a sampling flow will not give rise to a change in concentration at any point in the cloud. It is therefore possible to design low velocity sampling nozzles for collecting bulk samples of dust from plant atmospheres. Such elutriation nozzles can be particularly useful where bulk samples of dust are required in the pneumoconiotically active range since they can be designed to cut at any desired particle size. One such nozzle consists of a rectangular duct 4 cm. × 6 cm. cross section and 20 cm. long having internal shelves set 1 cm. apart. If a stream of air is drawn through at a rate of 250 l. per hour all particles of density 2g/cm.^{3} and greater than 5μ diameter will settle in the nozzle and the < 5μ fraction can then be trapped in a small cyclone or other suitable device and weighed. The concentration in the atmosphere can then be calculated in terms of the actual volume of air sampled and size analyses can also be carried out upon the collected fractions.

Such elutriation nozzles can only be used for sampling mists for determination of weight concentration: they are not generally applicable for collecting mist samples for size analysis. Where such data are required a more suitable instrument is the cascade impactor (May, 1945). It consists of a number of nozzles in series set close to microscope slides upon which are spread a thin sticky film in which the droplets to be collected are immiscible. The cross sections of the nozzles and their separation from the slides decreases through the series thus causing any stream of mist-laden air which may be drawn

through the impactor to emerge with increasing velocity from each successive nozzle. This increasing velocity and the corresponding decrease of the turning circles of the emergent jets as the air stream meets the various microscope slides results in smaller and smaller particles being tangentially thrown out from the streamlines to make contact with the sticky films. The main difficulty with this type of apparatus is so to adjust the volume of air sampled that sufficient of the largest particles are trapped on the first slide to ensure a statistically accurate analysis without producing too dense a deposit of fine particles on the last slide. There is, moreover, the inherent disadvantage that individual particle counts have to be made on each slide which have then to be calculated as a composite size analysis.

Where a potential silicosis or pneumoconiosis hazard is under investigation the data generally required are the number of potentially active particles in suspension rather than a weight concentration. In such circumstances it is generally sufficient to extract a sample of the dust from the ambient atmosphere by means of a thermal precipitator (Green and Watson, 1935). This instrument depends for its action upon the phenomenon of the dust-free space around hot bodies. It consists essentially of a resistance wire heated by means of a 2-volt accumulator controlled at a constant temperature by means of a rheostat. The wire is bounded on either side by two parallel cover slips set within the dust-free space and kept cool by brass backing plugs. When a slow stream of dusty gas passes the heated wire there is a movement of the particles in the " cold " direction. The thermal precipitator has been proved in practice to be a very efficient sampling device.

The main disadvantage of the instrument in its original form is that the dust particles are precipitated in a narrow band in which the concentration of particles is heaviest nearest the centre line tailing off towards the edges of the trace. This means when the trace is being counted and sized under the microscope that instead of being able to select representative areas for sizing, complete strips of the trace have to be examined at right angles to its axis and it is usually very difficult to decide at what point the trace ends. To overcome this disadvantage Wainwright and Walton (private communication) have designed a modified precipitator in which one of the cover slips may be oscillated by means of a cam mechanism backwards and forwards across the heater wire in a direction at right angles to its axis. This produces a relatively wide trace of even density of deposit from which typical areas may be selected for counting and sizing.

While the original thermal precipitator was designed for use with the light microscope the increasing interest in particles less than 1μ has rendered it necessary to extend the investigation into the range of the electron microscope. The thermal precipitator, whether in its original or modified oscillating form, can be easily modified to accommodate electron microscope grids in small depressions in the brass backing plugs.

Methods of Size Analysis.—The choice of a suitable method of size analysis is a question which until recently has not received adequate consideration, far too many people selecting a method by personal preference very often without taking any steps to see whether the technique selected is really accurate.

There are three main methods of size analysis available for air-borne particles: microscopical examination, sedimentation, and elutriation; I.C.I. has over a number of years investigated many techniques under these three heads and has developed ones which can at any rate be relied upon to give results of known reproducibility. In certain cases, as for instance when examining mist deposits collected in sampling cells or thermal precipitator traces, the nature of the deposit will limit the investigator to size analysis by microscopical examination. On the other hand, if, for example, a bulk sample of dust is available for the purpose of designing a wet scrubber for a plant ventilation system the most suitable method of size analysis would be by water sedimentation since the actual data required are the falling speeds of particles rather than their actual diameters. Similar considerations apply to air elutriation methods which would be particularly applicable where a determination was being made of the dust deposition round a factory chimney.

While considering the general question of size analysis it is important to realize that the parameter of particle size is different from the various methods of analysis. In the case of sedimentation or elutriation analysis where falling speeds are measured, the diameters are expressed in terms of the " equivalent sphere ", which is a hypothetical sphere of the same density as that of the particle measured and which has the same falling speed under identical conditions. In the case of microscopical examination the diameter measured is that of the " equivalent projected area ", *i.e.*, of a circle of the same area as the projected area of the particle. This is not necessarily the same as the diameter of the equivalent sphere and it must not be expected that size analyses by sedimentation and microscopical examination carried out on identical samples will give the same result.

Size Analysis by Microscopical Examination.—With this method it is now usual to match the particles against a series of graduated circles on a graticule which may be either set in the focal plane of the microscope eyepiece or in the case of the projection microscope may be embodied in the projection screen. The particles are counted and grouped into size ranges equated to a common area of slide examined, which can be expressed as number percentages or else as weight percentages by multiplying the number of particles per unit area in each size range by the cube of the corresponding mean particle size. In this latter case, since a few large particles exert a considerable effect on the weight distribution analysis, it is essential to count sufficient of these particles to ensure an analysis of the required accuracy. This whole question has been examined statistically and it is now possible to carry out a size analysis on a weight basis at any given limit of reproducibility for the largest particles and to ensure that this level is maintained throughout the analysis (Fairs, 1951).

In the case of the light microscope under optimum conditions of adjustment and illumination and with the

highest quality of optical equipment it is possible to resolve particles as small as about 0·3μ. It is, however, important to realize that below about 1μ it is impossible to differentiate between images of larger particles and diffraction halos of much smaller particles. It is therefore becoming general practice to restrict the use of the microscope to the range 76μ – 1μ. This has an important bearing on analyses of thermal precipitator traces which have in the past been quoted as low as about 0·2μ. The optical limitations of the method are, however, now beginning to be realized and where large-scale investigations of thermal precipitator traces have to be carried out below the limiting value certain investigators are now using the electron microscope instead of the light microscope.

Size Analysis by Sedimentation and Elutriation.—The general principle underlying all sedimentation analyses is to measure the rates of fall of the particles in suspension, and then to convert these rates of fall into particle diameters by means of Stokes law.

$$V = \frac{1}{18} \frac{g(\sigma - \rho)}{\eta} d^2$$

where V = falling speed
g = gravitational constant
d = particle diameter
σ = particle density
ρ = density of suspending fluid
η = viscosity of suspending fluid
All the factors in the equation are in consistent units.

This would be a simple matter if the particles were of uniform size but in the usual dispersion encountered which has a range of sizes the normal procedure is to measure the change in concentration of the suspension at definite time intervals at which it is known that all particles greater than a certain size have settled out. Stokes law only holds for conditions of free settling, and in order to achieve this condition the concentration of the suspension must not be greater than about 0·2% by volume, which raises some difficulty in measuring changes in concentration at the end of an analysis when most of the particles have settled out. This difficulty has been overcome in the I.C.I. sedimentation apparatus (Stairmand, 1947). This consists of a sedimentation tube connected by means of a side arm to a reservoir which contains clear suspending medium. A quick release run off is provided at the bottom of the sedimentation tube below the side arm which when opened allows all the sedimented particles to be flushed out by means of a stream of clear liquid from the reservoir, the weight of particles in the collected fraction being estimated by any convenient method. This procedure is very much more sensitive than any which measures the amount of solid in a sample withdrawn from the suspension itself apart from the dangers of causing disturbances in the suspension thereby. By this means sufficiently dilute suspensions can be employed to ensure that hindered settling and mass convection effects are prevented. In all sedimentation analyses complete dispersion of the particles in the suspending medium must be achieved by the addition of an appropriate dispersing agent, satisfactory dispersion being checked by examination of a drop of dispersion under the microscope.

Generally similar techniques are used in the case of elutriation. In this case a sample of the powder is subjected to a current of air under such conditions that any aggregates are broken down, the dispersed particles being passed into an elutriation vessel. The air rate is so adjusted that the average linear velocity in an upward direction in the vessel is equal to the free falling speed of the particles at which it is desired to cut. A satisfactory apparatus of this type is the Roller elutriator (Roller, 1931) which consists of a U tube containing the powder sample which is oscillated against a spring by means of a cam mechanism, while a stream of air is directed against the heap of powder, the dispersed powder being carried into the elutriation vessel and the material less than the "cut" size passing forward and being collected in a Soxhlet thimble. When elutriation of the finest particles is complete the air rate is increased and the next fraction is removed, the full analysis taking about four to eight hours.

For analyses of friable powders which might break down under the lengthy and violent action of the Roller apparatus, I.C.I. has developed a rapid elutriator which will give a reasonably accurate analysis involving six cuts in about 30 minutes. This apparatus is very simple and consists of a vertical elutriation tube which is made in two halves joined by flanged ends (Stairmand, 1951b). A thin gauze is fitted between these flanges which serves as a support for the sample to be elutriated. The lower end of the tube is connected to a flowmeter and the upper end through a Soxhlet thimble filter to a vacuum supply. As with the Roller apparatus the smallest particles are drawn off first but in this case elutriation for each size fraction is only carried out for 30 seconds since it is found that elutriation of most non-sticky powders is reasonably complete in this time.

References

Fairs, G. L. (1951). *J. roy. micr. Soc.*, **71**, 209.
Green, H. L., and Watson, H. H. (1935). *Spec. Rep. Ser. med. Res. Coun. (Lond.)*, No. 199.
May, K. R. (1945). *J. sci. Instrum.*, **22**, 187.
Roller, P. S. (1931). *Industr. Engng Chem.* (Anal. Ed.), 3, 212.
Stairmand, C. J. (1947). "Symposium on Particle Size Analysis." Supplement to *Trans. Instn chem. Engrs (Lond.)*, **25**.
—— (1951a). *Trans. Instn chem. Engrs (Lond.)*, **29**, 15.
—— (1951b). *Engineering*, **171**, 585.
Walton, W. H. (1954). "*The Physics of Particle Size.*" *Brit. J. appl. Phys.*, Suppl. No. 3, p. S.29 [Paper A.5].

In the subsequent discussion the President pointed out that in practice it was necessary to use the best sampling instrument available without waiting for the ideal; in fact, he had been using the same instrument for 20 years to cover a large part of routine dust sampling.

Control of the Fluorine Hazard

J. D. PATERSON

From the Medical Department, Imperial Chemical Industries Ltd., General Chemical Division

In view of the ever increasing number of industrial applications of fluorine-containing compounds, and the dearth of references to its effects in the literature, an account of factory experience may be of interest.

The most common references to fluorine have been with regard to the controversy as to whether or not water supplies should have fluorine compounds added as a means of reducing the incidence of dental caries in children. This paper deals, however, with hydrofluoric acid, which is quite a different proposition from the sodium silico-fluoride generally used in the fluoridation of water.

Experience with the very reactive compounds of fluorine leads us to the view that, considering only the acute effects and ignoring the chronic effects, they are even more severe in their action than mustard gas.

In the design of plant the following points should be borne in mind:

(1) The possibility of the material coming in contact with the operators should be reduced to the minimum.

(2) Adequate protective clothing should be provided so that if the material does come in contact with the operator no adverse effects are produced.

(3) Means of decontaminating or treating the operator should be available if, by mischance, he does come in contact with the material.

(4) There should be effective medical supervision.

The hazard with hydrofluoric acid is both acute and chronic. The acute hazard is that in concentrations of over 20% it will cause damage to body tissue, and in concentrations of over 60% this damage will be immediately apparent.

Like other acids in contact with the skin, it will cause dehydration and corrosion. It has, however, in addition to these, a unique effect. The fluorine ion will penetrate the deep layers of the tissue and will exert a dissolving action on the cellular membranes, causing a liquescent necrosis which, when it reaches bone, causes decalcification. The more concentrated the acid, the longer the period of contact and the more delicate the tissue, the more rapid in onset and the more intense will be the pain phenomena and the deeper will be the necrosis.

The chronic hazard is the possibility of the development of fluorosis, which is a condition of sclerosis of bone, and in extreme cases of ossification of the ligaments.

How, then, can these hazards, the acute and the chronic, be controlled ?

First consideration must be given to ways and means of confining the material to the interior of the plant; this is the province of the engineers and chemists, but they require and seek the advice of the industrial medical officer about the dangers to which operators might be exposed. It is at the design stage that much can be done to eliminate hazards by remembering that it is easier and cheaper to incorporate safety devices during construction than after completion, and that good design goes a long way towards preventing accidents.

FIG. 1.—Photograph showing type of protective clothing worn by operators on the high fluoridation plant when engaged in work which might expose them to heavy contamination.

The reactivity of hydrofluoric acid is probably sufficient in itself to make the design staff do all in their power to keep the material enclosed, if only for technical reasons, as not only does it attack body tissue but also a diversity of normal construction materials. Such plant, therefore, is well on its way to being leak-proof without our even considering the medical point of view. The chance of leakage must, nevertheless, be kept in mind as it is impossible to neutralize. Some means of diluting any fume to a concentration at which it would be harmless is also essential. This is done by building the plant virtually in the open air.

The next point is how to protect the worker. It is our experience that once a man is convinced that the risks are serious he will wear the protective clothing provided, and indeed will complain if he does not consider it sufficient. No persuasion is necessary if the material is

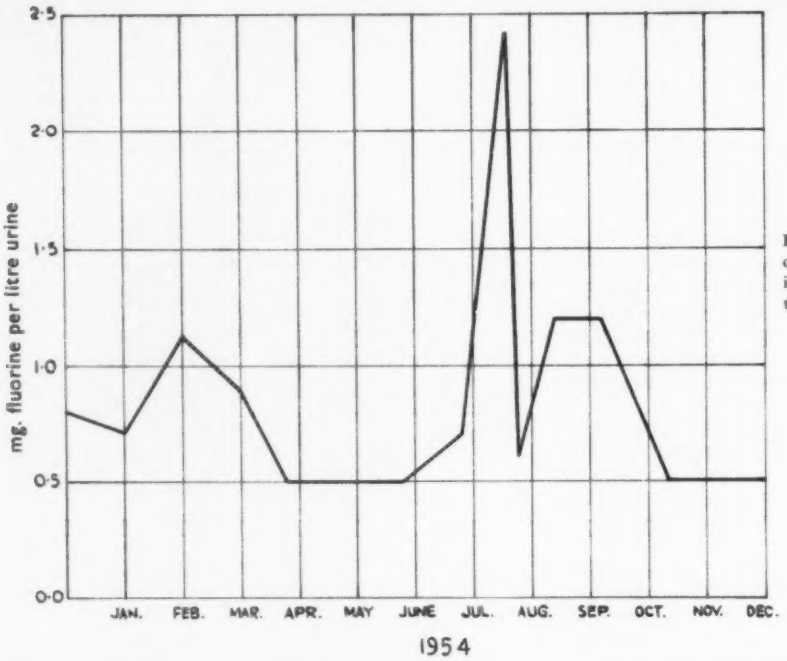

FIG. 2.—Graph showing excretion rate of fluorine in milligrams per litre of urine in process workers illustrating rapid return to normal after a rise in rate.

such as hydrofluoric acid, sodium, or hydrochloric acid, but it is a little more difficult with, for example, benzene, where the risk is not so obvious.

In the early days it was decided that full protective clothing should be worn at all times, but it was considered that it would be a burden on the men to wear indefinitely this outfit, consisting of woollen suit, oilskin coat, rubber boots, gloves, and headpiece. The dangers were explained to the men and an undertaking given that the clothing would be modified as soon as it was considered safe to do so. After about six months the protection was reduced to overalls, boots, gloves, and headpiece (Fig. 1) with the full rig-out being used only on breakdowns and special maintenance work.

It is imperative, on a plant which requires extensive protective clothing to be worn, to provide changing and messing accommodation close at hand. This is built as a separate block into which is incorporated a first-aid room with shower baths and an alarm system to alert the Medical Department and summon a nurse.

Where protective clothing is worn a system of inspection and repair must be organized, particularly with regard to gloves, which have the hardest wear. The majority of burns have been due to penetration of a glove through a pin hole, and to reduce such risks as much as possible the gloves used on the plant are inspected daily and withdrawn from service if any flaw is noted.

Protective clothing furnishes a defence against the acute effects of hydrofluoric acid, and we are confident that, with normal operating, the possibility of fluorosis developing is remote. Nevertheless, when special maintenance is required and parts which are heavily contaminated are being handled, the risk is present. It is overcome by wearing full protective clothing and also a fresh-air hood, to prevent the inhalation of fumes.

The system of medical supervision employed is designed to draw attention to chronic effects in workers at an early stage. Before being employed on the plant, operatives are required to pass a medical examination. At this examination, which includes a radiological examination of the chest, spine, and pelvis, those who show abnormalities of heart, lungs, or skeleton are excluded, as are those of low mentality or hyperexcitability, or who have very defective vision.

When the plant first began producing each operator had a weekly urine test and an estimation of the fluorine content was made. It is known that if this content does not exceed 10 mg./l. the possibility of fluorosis developing is slight. It is our policy to take a figure of 1 mg./l. as a reasonable and safe excretion rate.

These estimations were, in the first instance, carried out weekly, but the excretion rate of fluorine is so high and a return to normal level so quick, that there was a chance of missing a raised level unless they were done daily. After a little time it was apparent that the excretion rates were satisfactory, and it was decided to test the men not so much as individuals, but as a check on each part of the plant at weekly intervals. A rota which ensures that each job is covered weekly is now in operation and has been a great help as an indicator to the plant supervisors of points requiring attention which would otherwise remain unnoticed.

Each operative has a blood examination every six months, a clinical examination yearly, and biennial repeat radiograph of the chest, spine, and pelvis. At one

time they had dental examinations every six months, but these have been discontinued.

In spite of all these precautions we still occasionally have to treat burns due to hydrofluoric acid, but we have been fortunate in that we have never had a really serious burn, nor have we had a burn of the eye.

In all cases the symptoms are the same. There is a feeling of tingling over the affected area, followed by throbbing and severe pain. These symptoms may be delayed for some hours or they may occur very quickly, depending on the strength of the hydrofluoric acid and the duration of contact. In either case the pain is agonizing.

What happens when a man is burned ? First of all he is instructed to wash the part under copious amounts of water and then a dressing of magnesium oxide paste is applied and rubbed in. This, in the very mild burns, is usually sufficient. In the more severe burns, however, the standard treatment adopted is the injection of 10% calcium gluconate into and around the burned area until a weal is formed. It is very pleasing to see the relief from pain which this gives—in many cases before the injection is complete.

The men know of this relief and even if they have gone home before the onset of symptoms they will still come into the Works for treatment. It has been suggested that it may be necessary to give either a general or a local anaesthetic before injecting. My experience with burns we have had has been that it has not been necessary. Perhaps this is due to the cooperation we get from the men, who are prepared to suffer some discomfort during injection as they know of the relief which it brings, and also to the relatively minor nature of the burns. I can well imagine, however, that without this cooperation, or with severe burns, anaesthesia might be necessary. Most promising clinical trials are being carried out with a new anaesthetic called " fluothane ". In the future, if anaesthesia is necessary, we may be giving one fluorine compound in order to relieve the effects of another.

Other compounds, including chlorine and bromine tri-fluorides, are also very reactive; so much so that in contact with the skin only thermal burns occur without the penetrating effect shown by hydrofluoric acid. Fluorine refrigerants and fluorocarbons give rise to no hazard except in so far as the handling of the elementary fluorine used in their manufacture is concerned.

A discussion followed on the mechanisms by which the relief given by magnesium oxide and calcium gluconate might be explained, but beyond the fact that magnesium fluoride was insoluble and that magnesium hydroxide was particularly effective when mixed with glycerol, no definite conclusions could be reached.

It was stated that sodium silico-fluoride gave a severe skin reaction; this substance is used in the manufacture of latex foam and for destroying vermin.

The minimal concentration of hydrofluoric acid likely to be hazardous was discussed, and it was claimed that noticeable effects could be produced by 3% solution with long exposure. Below 20% pain was caused but no burning. Long experience in a workshop where glass was etched with hydrofluoric acid had revealed no sign of trouble.

It was considered that the intake of vapour by inhalation was likely to be too low to cause fluorosis, which was probably associated with ingestion over a long period. Sixty to 70% of the intake is normally excreted.

BIBLIOGRAPHY

Bartalini, E., and Grianti, V. (1953). *Rass. Med. industr.*, **22**, 34.
Dale, R. H. (1951). *Brit. med. J.*, **1**, 728.
Jones, A. Thelwall (1939). *J. industr. Hyg.*, **21**, 205.
Schuermann, H. (1937). *Derm. Wschr.*, **104**, 661.

B.M.A. Occupational Health Prize

The **Occupational Health Prize** was established by the Association for the purpose of encouraging interest and research in the field of occupational health. The Council of the British Medical Association is prepared to consider the award of this Prize which consists of a certificate and £50 in the year 1957.

Any member of the Association who is engaged in the practice of occupational health, either whole-time or part-time, is eligible to compete for the prize. Candidates may select their own subject.

Entries should be submitted in a form suitable for publication and must include personal observations and experiences collected by the candidates in the course of their work. If no entry is of sufficient merit no award will be made. Candidates should confine their attention to their own observations rather than to comments on previously published work on the subject, though reference to current literature should not be omitted when it bears directly on their results, their interpretations, and their conclusions.

Essays, or whatever form the candidate desires his work to take, must be sent to the Secretary, British Medical Association, B.M.A. House, Tavistock Square, London, W.C.1, not later than January 31, 1957.

No study or essay that has been published in the medical press or elsewhere will be considered eligible for the prize, and a contribution offered in one year cannot be accepted in any subsequent year unless it includes evidence of further work. A previous prize-winner is not precluded from entering.

If any question arises in reference to the eligibility of the candidate or the admissibility of his or her essay, the decision of the Council on any such point shall be final.

Preliminary notice of entry for this competition is required on a form of application to be obtained from the Secretary.

Each entry must be typewritten or printed on one side of the paper only, and accompanied by a note of the candidate's name and address.

No definite limits are laid down as to the length of essays, but the Council anticipates that for this Competition, essays should consist of between 3,000 and 10,000 words.

Enquiries relative to the prize should be addressed to the Secretary.

BOOK REVIEWS

Lung Function in Coalworkers' Pneumoconiosis. By J. C. Gilson and P. Hugh-Jones. (Pp. xii + 266; 15 plates. 21*s*.) London: H.M. Stationery Office, 1955.

This is by far the most authoritative report that has appeared on this subject. The first part reviews the nature of the disease, and the radiological, pathological, and clinical features. The classification by radiological changes is precisely defined and compared with other classifications so far employed. Previous work on lung function in this disease is described at great length. As in most extensive reviews it is rather difficult to appreciate the best work of pioneers in the subject.

In a carefully designed series of experiments, so that the effects of age and radiological category could be separated, the authors showed that the best index of breathlessness was the exercise ventilation expressed as a percentage of the maximum voluntary ventilation. This is in agreement with previous work but it is the first time that the effects of age and radiological category have been clearly separated. They found that there is little increase in dyspnœa with increasing degree of simple pneumoconiosis except in the older patients with the severest simple form of the disease. In men with complicated pneumoconiosis dyspnoea was marked. The normal effect of age on shortness of breath increased considerably with increasing severity of the disease.

Shortness of breath was found to be associated with a reduction in the maximum voluntary ventilation and not with an increase in exercise ventilation. The authors emphasize that the degree of shortness of breath and rise of dyspnoeic index, although correlating well with degree of disease and age in groups, showed less satisfactory correlation in individual subjects. A most interesting finding was a slight but definite increase of dyspnoea (as measured by the dyspnoeic index) in normal miners as compared with control non-miners.

The investigations concerning blood oxygenation and gases are trivial and remarkably unsophisticated. Gas distribution and transfer are studied by the helium mixing and carbon monoxide uptake techniques, performed simultaneously. Although showing great ingenuity in concept the authors will leave the average reader baffled by complicated mathematical analyses. Their conclusions are that inequality of ventilation is the main cause of impaired gas transfer in pneumoconiosis and that diffusing capacity across the alveolo-capillary membrane is probably not affected. As is so often the case with carbon monoxide studies there is a large element of doubt as to what exactly is being measured and it is a pity that Riley's classical tension techniques have not been applied to this disease under these beautifully controlled conditions.

The circulatory aspect of lung function, which may well be an important factor in prognosis, is also neglected. Although appreciating the difficulties of standard modern techniques, particularly cardiac catheterization, in this environment, it is sad to see "cardiological results" carefully separated from "physiological results".

The interrelation of tests by factor analysis is intriguing although the conclusion that size, ventilatory power, gas distribution, and gas transfer are the basic independent attributes of the lung will not surprise respiratory physiologists.

The discussion and conclusions concerning the relationship of their findings to compensation are realistic and show how increased knowledge reveals new problems as well as solving old ones.

It is to be hoped that the Pneumoconiosis Research Unit will repeat certain aspects of this work using techniques such as the measurement of respiratory work, blood gas tensions, and cardiac catheterization.

Mr. Oldham's wise counsel on the planning and interpretation of experiments is such a dominating feature of this work that he could well have been accorded full status as an author.

Dr. Gilson and Dr. Hugh-Jones are to be congratulated on this important contribution which is a definite milestone in the understanding of this disease.

K. W. DONALD

La Silico-Tuberculose. By Astrid Schweitzer. (Pp. 200; 23 figures. Price not stated.) S. A. Paris: Librairie Maloine. 1956.

Dr. Schweitzer, of the medical faculty of Strasbourg, has studied pneumoconiosis at Merlebach, Nancy, Bochum, and Hasselt. She should therefore be well qualified to present the views of the leading French, German, and Belgian authorities. In this monograph she attempts a comprehensive account of silico-tuberculosis. After a brief historical introduction, the pathogenesis and some of the results of animal experiment are outlined. The morbid anatomy, clinical features, prognosis, and treatment are discussed in subsequent chapters and the book concludes with a description of the medico-legal aspects, economic importance, and prevention of the disease.

A book of this kind could be valuable. It is a pity, therefore, that the present work is inadequate, often inaccurate, and lacking in critical balance. The author makes little attempt to differentiate between classical silicosis and pneumoconiosis of coalworkers. The descriptive cases (pages 51-56), for example, include workers exposed to dusts with a high free silica content as well as to coal-mine dust, yet all are classified together.

The resulting confusion is the more regrettable at a time when there is a growing understanding of the differences between the two conditions, particularly in their liability to open tuberculosis.

To the English reader the omission of British references is striking. Thus in the chapter on experimental pathology, while the views of Professor Policard (1933) on the pathogenesis of silicosis are described, there is no mention of the work of Professor King and his colleagues. The "two disease" hypothesis that simple pneumoconiosis of coalworkers is due to inhalation of coal dust and progressive massive fibrosis to tuberculosis is never clearly stated. Instead, on page 29, Gough's views on coal-miners' pneumoconiosis are confused with his views on classical silicosis and a misleading impression is created. The I.L.O. international classification (1950) of chest radiographs for pneumoconiosis has perhaps particular relevance to this hypothesis; but in any case, it should surely have been briefly described. The illuminating results of epidemiological research (other than a brief mention of occupational mortality) are almost completely ignored.

The detailed account of the medico-legal aspects of silico-tuberculosis in France and Germany may prove useful to doctors in those countries concerned with compensation. The situation in Great Britain, however, is dismissed too briefly to be of any value.

The book is well produced and the reproductions of the radiographs are generally adequate, though the excavation said to be present in the left upper lobe in Fig. 6 (page 55) is not seen.

Dr. Schweitzer has attempted a difficult task. It is regrettable that her book—obviously the result of considerable labour—adds little to our understanding or knowledge of silico-tuberculosis.

I. T. T. HIGGINS

Peaceful Uses of Atomic Energy. Proceedings of the International Conference in Geneva, August, 1955, Volume 10: *Radioactive Isotopes and Nuclear Radiations in Medicine.* (Pp. ix + 544; illustrated. 57*s.*; $8.00.) London: H.M.S.O; New York: United Nations. 1956.

The applications of radioactive isotopes and nuclear radiations in therapeutic radiology and in the diagnosis and study of disease were discussed in some detail at the Geneva Conference; those who are interested in these branches of medicine will find a great deal of useful and up-to-date information in the 85 papers contained in this volume. The impact of nuclear energy on radiotherapy has turned out, so far, to be less dramatic than many of the ardent prognostications of five and 10 years ago. Considerable progress has been made, however, in the refinement of well-established techniques and in the introduction of new types of radioactive sources, and there are reasonable grounds for optimism about the uses of internally administered radioisotopes, particularly in the treatment of certain diseases of the blood and of the thyroid gland.

The greater part of the volume is concerned with the uses of radioactive isotopes in the diagnosis and study of disease and it is evident that these techniques have already made an impressive contribution in the realm of physiology and pathology.

The biological effects of radiation and the problems of radiological protection are dealt with in volumes 11 and 13 of the proceedings of the Geneva Conference.

A. S. MCLEAN

Peaceful Uses of Atomic Energy. Proceedings of the International Conference held in Geneva, August, 1955. Volume 11: *Biological Effects of Radiation.* (Pp. 402; illustrated. 57*s.*; $8.00.) New York: United Nations. 1956.

It is of fundamental importance that the criteria of safety in radiation work should be founded upon a thorough understanding of the nature of the effects of radiation on human beings. From the point of view of present and future problems, it is fortunate that a considerable amount of useful information has been forthcoming from studies of the injuries sustained not uncommonly by the early radiation workers. Nevertheless, a great deal of animal experimental work has been required in order to fill in the gaps. It is never entirely satisfactory, however, to have to deduce the reactions of one species from observations on the behaviour of others and, to allow for uncertainties in interpretation, the whole approach to radiological safety has been necessarily conservative. For this reason, there can be no doubt about the need for further information about the effects of radiation on human beings.

A particularly important feature of this volume is the fact that a considerable proportion of the 63 papers contained in it are concerned with human aspects of radiobiology; it is, therefore, a very valuable addition to the literature on the biological effects of radiation. The proceedings are presented in sections—on modes of radiation injury, carcinogenesis and metabolism of bone-seeking isotopes, effects on the reproductive system, mechanisms of radiation injury, protection, recovery, and genetics—and in each, there are several interesting papers. The standard of presentation is so high that it would be impossible to single out any one contribution for special mention. Indeed, the list of authors shows that the cream of international opinion was represented at the conference.

It is obvious that, as a scientific meeting, the Geneva Conference was a notable success. No less important, however, was its contribution to international understanding and goodwill.

A. S. MCLEAN

Psychological Tests for Accident Proneness and Industrial Proficiency. By E. G. Chambers. Medical Research Council Memorandum No. 31. (2*s.*). London: H.M. Stationery Office.

In 1919, the Industrial Fatigue Research Board published a study by Greenwood and Woods, "The Incidence

of Industrial Accidents, with Special Reference to Multiple Accidents ". This was closely followed by other contributions, mainly by Greenwood, and the statistical concept of accident proneness was launched. Although there have been later criticisms, it is a tribute to the careful observation and analysis of Greenwood and his colleagues that the idea of inherent individual differences in accident liability was, and continues to be accepted.

After this statistical demonstration, interest in the problem became more psychological, and research was undertaken to discover what personal qualities were associated with accident proneness. The main work in this country was carried out by E. G. Chambers and E. Farmer, as investigators for the Industrial Fatigue (later Health) Research Board. Their reports—Nos. 38, 55, 68, 74, and 84—cover work done from 1927 to 1940. These reports are still essential literature for all seriously concerned with the problems of accidents. They are, unfortunately, all out of print, and must be tracked down zealously in medical school libraries or psychology department libraries.

The present publication is an attempt to remedy this situation; it is a summary of these reports. Inevitably, some detail is lost. The full tables and graphical display of the original reports are omitted, and the description of the psychological measures employed is somewhat brief. But the main conclusions are brought out very clearly, and as a result it is easier to observe the relationship between sensorimotor, aestheto-kinetic, intelligence, mechanical aptitude and ability, and other tests of accident performance and proficiency ratings. Thus the memorandum may well be better suited to those whose interests are general and practical, rather than to those who are more concerned with research details.

The author has carefully and deliberately avoided interpolation of new material, either of direct evidence or interpreting the original data. This is particularly noticeable in discussion of the relation of the test performances to accident experience. Chambers and Farmer were the first to observe that complex tests were better predictors than tests based on simpler psychophysical processes. Later work has followed this example and treated accident proneness more as a behavioural syndrome than as a simple defect. Mr. Chambers has done great service in restoring to general circulation the essentials of the earlier work; perhaps it is not too much to hope that he will also give his account of its later development.

J. WHITFIELD

Textbook of Occupational Therapy with Chief Reference to Psychological Medicine. By Eamon N. M. O'Sullivan. (Pp. x + 319. 21*s*.) London: H. K. Lewis. 1955.

Work therapy was often a polite and somewhat cynical way of describing the cheap labour used on the chores and odd jobs of the mental hospital kitchen and farm. The surprisingly good results of this rather unscientific " therapy " in so many patients has long ago removed the cynicism and made overdue a proper study of how it works. But it is a difficult step, particularly in mental illness, from demonstrating the useful effects of a particular treatment to understanding the processes involved. Occupational therapy is now universally regarded as one of the mainstays of the in-patient care for mental as well as many other diseases, but its claim to be a science will not be accepted by all. Dr. O'Sullivan's textbook does little to persuade us of its scientific basis, though it is a good practical introduction to the subject for those training to be occupational therapists.

After a brief historical preamble the book becomes a description of the occupational therapy which is arranged for nearly all the patients in Killarney Mental Hospital. There is a brief section dealing with the classification of mental illness and another on " craft analysis " in which an attempt is made to define principles upon which the job may be best suited to the patient and his disease. It is in dealing with this latter problem by generalizations that the occupational therapist is on most dangerous ground and it is here that the main emphasis must be upon discussion with other members of the treatment team, rather than upon classifications or " principles ". The last part of the book is a useful and detailed description of various orthodox procedures in occupational therapy such as weaving, woodwork, canecraft, etc., with analyses of them from practical, therapeutic, and economic points of view. Emphasis is placed throughout upon the " socializing " effect as well as the individual benefits of occupational therapy.

Work is only one small part of the treatments aimed at the controlled reintroduction of a normal social life to the mentally sick, but it was the earliest to be used and is the most widely applied. So far the theoretical framework is almost non-existent and, though Dr. O'Sullivan wisely does not speculate, he could perhaps, have listed for us some of the current hypotheses. We do not really know why doing things helps some people to get better; however, it does, and this book introduces us to the job of the occupational therapist and tells us how to organize a unit in a large mental hospital.

E. MAURICE BACKETT

INDEX
PAGES
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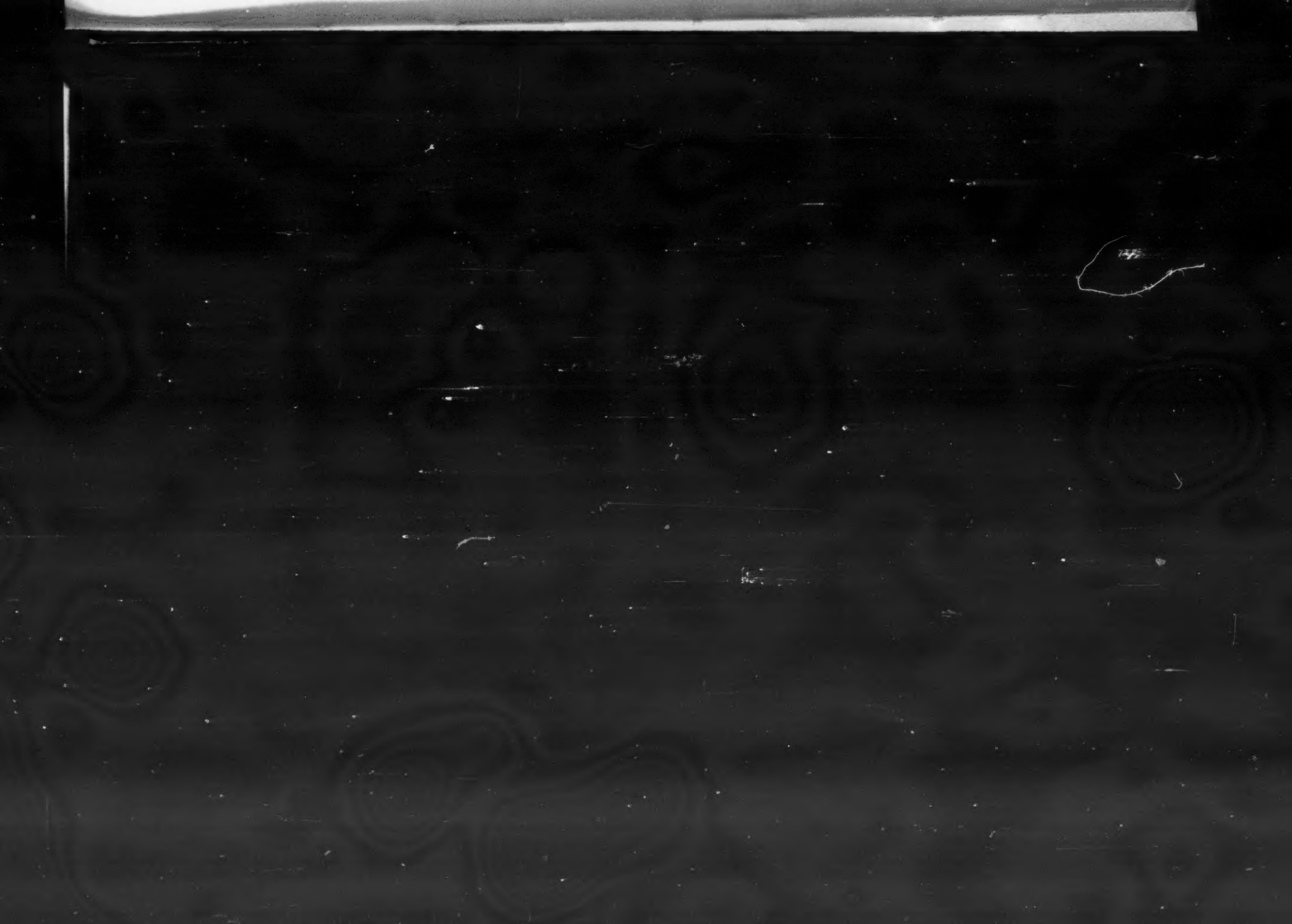

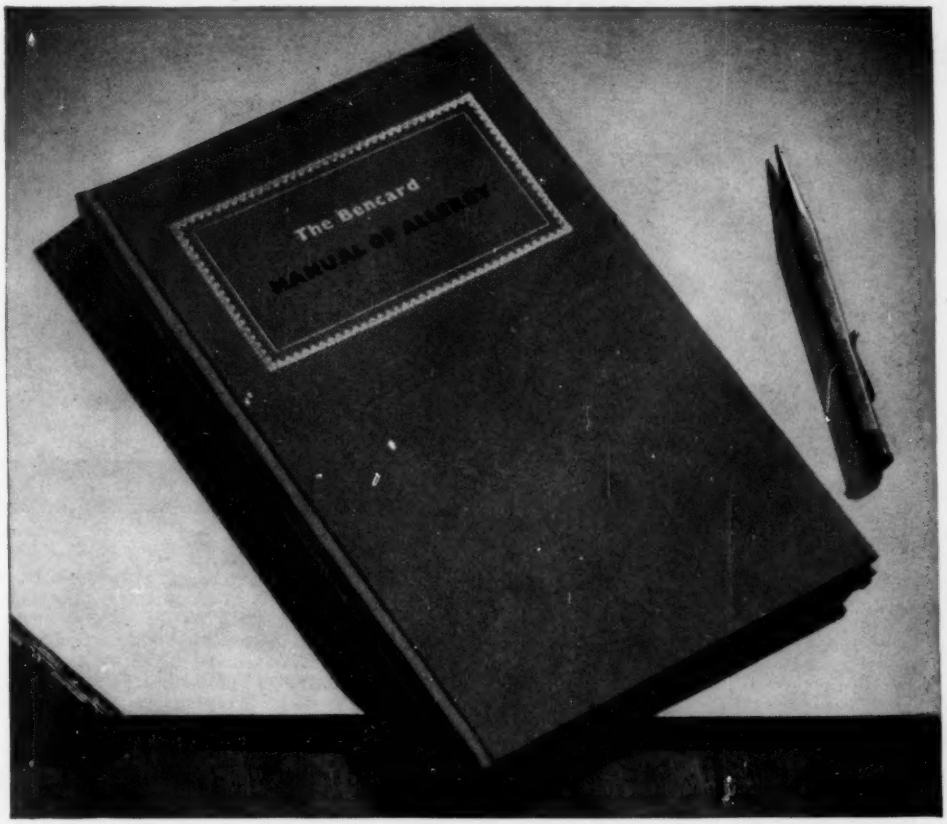

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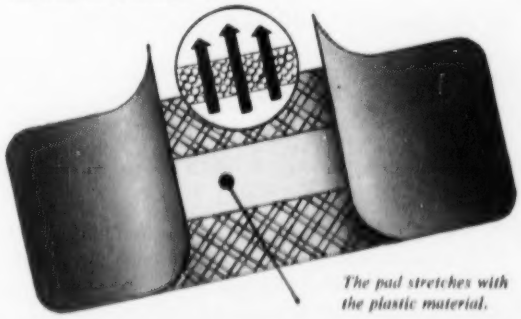

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